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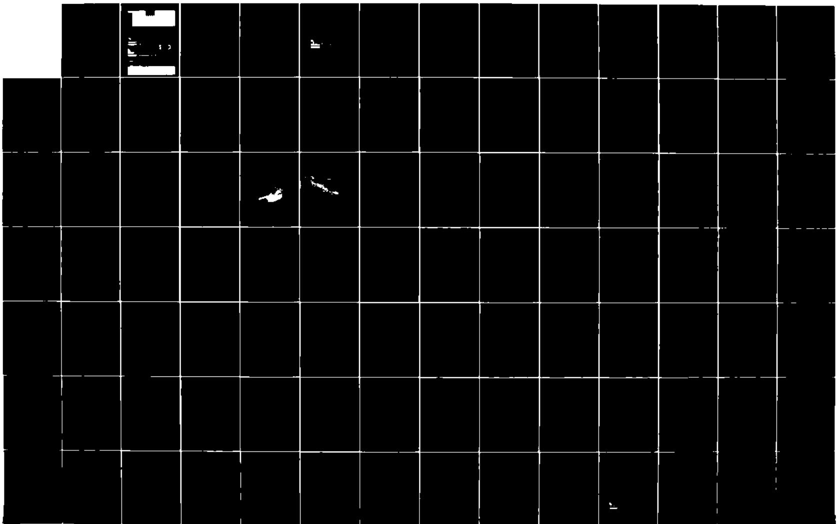

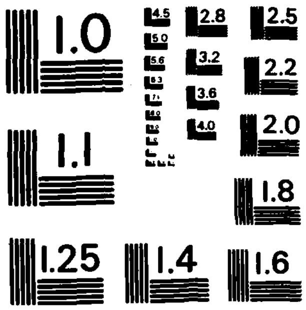

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GREAT I STUDY OF THE UPPER MISSISSIPPI RIVER

VOLUME 4

WATER QUALITY

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Report 4 consists of two parts. Part A discusses the water quality impacts of dredging and shipping activities, and also water quality standards and criteria from other sources of pollution.

Part B analyzes soil erosion from the Mississippi River's upland basin which settles into the backwaters and Lake Pepin. The effects of sedmentation are accelarated by the pooling effects of locks and dams.

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OUTLINE

GREAT I

SEPTEMBER 1980

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B. DREDGED MATERIAL USES
C. DREDGING REQUIREMENTS

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M. ENVIRONMENTAL IMPACT STATEMENT

F. WATER QUALITY

FOREWORD FROM THE GREAT TEAM

This report was prepared by the Water Quality Work Group of the Great River Environmental Action Team (GREAT I). The conclusions and recommendations contained in this report reflect the work performed by this work group only, within its specific area of expertise. Recommendations from this report will be considered in relation to other objectives for overall resource management and may be included in the final GREAT I report as considered appropriate by the GREAT I Team.

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THE WORK GROUP

The Water Quality Work Group (WQWG) is one of 12 work groups implemented under the auspices of GREAT I (Great River Environmental Action Team). The work group's responsibilities are primarily concerned with the water quality aspects of the GREAT I management and maintenance plan for the Upper Mississippi River.

SCOPE

The WQWG is responsible for those areas of the Upper Mississippi River basin under consideration by GREAT I: the Mississippi River from the head of navigation to Guttenberg, Iowa, and navigable portions of the lower Minnesota, lower St. Croix, and lower Black Rivers.

PARTICIPATION

According to the GREAT I Phase I Status Report (July 1976), "the Great River Environmental Action Team is a joint Federal-State study funded by Congress and State Governments." More correctly, funding was provided specifically for research and construction projects, but not for interagency representation in the work groups. This situation hampered efforts of the WQWG and made participation an additional work responsibility for representatives from the following agencies:

U.S. Environmental Protection Agency (EPA)
U.S. Army Corps of Engineers (Corps)
U.S. Soil Conservation Service (SCS)
U.S. Geological Survey (USGS)
U.S. Fish and Wildlife Service (FWS)
Minnesota Department of Natural Resources (MDNR)
Minnesota Pollution Control Agency (MPCA)
Wisconsin Department of Natural Resources (WDNR)

In addition, public participation by a representative from the Public Participation and Information Work Group was inconsistent but valuable. The State of Iowa did not participate in the WQWG effort.

Only representatives from the Corps, EPA, USGS, MPCA, and WDNR participated consistently on the WQWG. The effectiveness of the WQWG was further encumbered by the fact that individuals representing these agencies often changed during the course of the study. Funding of personnel responsible to the WQWG did not exist until April 1977 when a full-time coordinator was supported by GREAT I funding. This action facilitated significant progress and documentation of research.

OBJECTIVES AND PROBLEMS

Objectives and problem identification have suffered from lack of consistency and direction during the course of the study. Although GREAT was originally organized in response to public concern and lawsuits brought against Corps dredging practices, the objectives of the work group did not address these issues in the beginning. Reasons for this problem included a lack of clear direction from GREAT, differing opinions on the part of work group members as to the purpose of the WQWG, work group response to public input, and requests from other GREAT work groups. The effect of these factors can be observed in the changing report descriptions in the following table.

Table 1 - Summary of GREAT reports

Report	Objectives (Summary)	Methods of accomplishment	Comments
GREAT I Plan of Study (1975)	Identify and evaluate major influences on river water and sediment quality throughout the study area.	1) Assemble existing water and sediment quality data. 2) Conduct water and sediment quality surveys. 3) Develop a list of problem areas throughout the study area. 4) Investigate problem areas and recommendations.	Objectives and methods were based largely on opinions of work group members.
GREAT I Phase I Status Report (1976)	Identify and evaluate the major influences of dredging on river water and sediment quality throughout the study area.	1) Same as above. 2) Same as above. 3) Same as above. 4) Monitor and evaluate effects of dredging and navigation activities on water quality.	Town meetings were conducted with input to WQWG (some problems beyond the scope of the WQWG were identified).
GREAT I Draft Interim Report (1977)	Investigate and evaluate the effects on water quality of the primary river uses and associated maintenance.	1) Conduct field studies on effects of dredging and disposal on water quality. 2) Navigational effects field study and literature review. 3) Survey of sediment quality. 4) Studies on effectiveness of silt curtains and polymers.	Focus of activities is finally on dredging and navigation (primary problems identified). The silt studies of curtains and polymers were actually independent Corps projects
GREAT I Interim Status Report (1978)	Identify and evaluate major influence of dredging on river water and sediment quality throughout the study area.	1) Assemble existing water and sediment quality data. 2) Conduct water and sediment quality surveys. 3) Develop a list of problem areas throughout the study area. 4) Monitor and evaluate the effects of dredging and navigation activities on water quality.	Activities centered around dredging and navigation studies in 1977.

Two additional needs which were not listed as a part of the "Methods of Accomplishment" section in each of the four reports were: 1) development of conclusions and recommendations pertaining to future river use activities; and 2) drafting of the WQWG appendix to the final report.

One of the identified intents throughout all of the report objectives was to assemble existing water and sediment quality data. This has been done inasmuch as this information has related to write-up of work group research efforts. The work group recognizes the need for this type of compilation, but it is beyond the defined scope of the GREAT I effort.

Water and sediment quality surveys were another goal of the work group. However, since State and Federal agencies already have an ongoing network of water quality monitoring surveys, it has not been a priority of the work group to duplicate these efforts. The WQWG conducted a reconnaissance sediment quality survey in 1974. With work group aid, another sediment quality survey was designed in 1978 and is being implemented by the Corps. These surveys have contributed to a better understanding of existing conditions.

Water quality criteria and standards applicable to the GREAT I study area, as well as major problems of the area, will be addressed in a later section of this appendix. Existing criteria and standards can be applied to any potential or existing problem area within the GREAT I study boundaries.

ACCOMPLISHMENTS

Since 1976, the major thrust of work group research activity has focused on the water quality impacts of dredging, disposal, and navigation. Specific activities in this regard have included:

1. A Pilot study on the effects of hydraulic dredging and disposal on water quality of the Upper Mississippi River at Grey Cloud Island (1976).

Sediment and Erosion Work Group

Need for the study	GREAT objectives for the work group	Problems identified by the work group	Work
Channel maintenance is damaging the river environment.	1. Develop ways to reduce dredging. 2. Develop measures to preserve and enhance the environmental values of the river.	1. Streambank erosion on tributaries increases dredging requirements. 2. Secondary movement of dredged material affects backwaters and dredging requirements. 3. Fine sediment from upland erosion affects backwaters. 4. Lake Pepin is rapidly filling in as a result of sedimentation and dredging. 5. Backwaters and side channels are filling in and impairing recreational access. 6. Increased sedimentation is increasing flood elevations. 7. Accelerated sedimentation is shortening pool life. 8. Aquatic habitat is being lost as a result of sedimentation.	1. Identify s (problems 2. Determine tributari 3. Monitor ra sion with lem 2). 4. Determine and need 5. Determine (problems 6. Determine and metho (problems 7. Determine bank prote 8. Evaluate al mentation (problems 9. Inventory a 10. Prepare map group aids 11. Draft SEWG

dIment and Erosion Work Group planning process

	Work group objectives	Work group alternatives not addressed	Work group projects	Project results
ries in- s.	1. Identify sources of sedimentation (problems 1, 3, 4, 5, 7, 8).	1. Status quo (do nothing) - would subject resource to irreversible damage in a relatively short time (50- to 250-year life expectancy of backwaters).	1. Prepare sediment source maps (objectives 1, 2, 8, 10).	1. Critical fine and coarse sed sources identified (projec
material ging	2. Determine sediment contributions from tributaries (problems 1, 3, 4, 5, 7, 8).	2. Establish complete (one-quarter mile) cross section data - cost constraints.	2. Establish tributary monitoring statiors (objectives 1, 2, 8).	2. Backwaters and Lake Pepin wi in unless sedimentation is (projects 3, 4).
sion	3. Monitor rates of sedimentation and erosion within the river corridor (problem 2).	3. Nonpoint sediment pollution control demonstration project - beyond scope of GREAT, cost is prohibitive.	3. Monitor sediment rates in backwaters and Lake Pepin using cesium 137, fathometer, spud survey, and cross-section comparisons (objectives 4, 5, 8).	3. Streambank erosion is a maj of dredging required (proje 2, 5, 7).
in as a dredging.	4. Determine sediment rate at Lake Pepin and need for abatement (problem 4).	4. Determine sediment yield from dredged material disposal areas - quantity is relatively small with respect to total sediment yield.	4. Prepare vegetative inventory maps to show loss of aquatic habitat (objectives 1, 2, 3, 5, 8).	4. Aquatic habitat is being los sedimentation (project 4).
are reational	5. Determine sediment rate in backwaters (problems 3, 4, 5, 7, 8).		5. Evaluate and assign priorities to the main channel border for shoreline protection (objectives 1, 3, 4, 5, 8).	5. Side channels and backwaters being cut off by secondary of dredged material (proje
creasing	6. Determine critical sources and costs and methods for upland treatment (problems 3, 4, 7, 8).		6. Research and evaluate erosion and land treatment alternatives (objectives 6, 7, 8, 9).	6. Upland erosion is major sour fine sediments (projects 1, 6).
shortening	7. Determine methods and costs for streambank protection (problem 1).		7. Review progress of Chippewa River demonstration project (objectives 1, 2, 7, 8, 9).	7. Erosion control alternatives bank and upland) are very e to implement (projects 6 an
as a	8. Evaluate alternatives to reduce sedimentation in the river corridor (problems 1, 2, 3, 4, 5, 6, 7, 8).			8. Existing erosion (streambank control measures are not ca resolving sedimentation pro (project 6).
	9. Inventory and research existing data.			
	10. Prepare maps and illustrations as work group aids.			
	11. Draft SEWG appendix.			

[illegible]ts	Project results	Work group conclusions	Recommendations
[illegible] maps (objectives [illegible]itoring stations [illegible] in backwaters and [illegible]um 137, [illegible]athometer, [illegible]s-section compari-[illegible] [illegible] maps to show [illegible] objectives 1, 2, [illegible]orities to the main [illegible]reline protection [illegible], 5). [illegible]rosion and land [illegible] (objectives [illegible] river demon-[illegible] 1, 2, 7,	1. Critical fine and coarse sediment sources identified (projects 1, 2). 2. Backwaters and Lake Pepin will fill in unless sedimentation is reduced (projects 3, 4). 3. Streambank erosion is a major cause of dredging required (projects 1, 2, 5, 7). 4. Aquatic habitat is being lost to sedimentation (project 4). 5. Side channels and backwaters are being cut off by secondary movement of dredged material (projects 3, 4, 5). 6. Upland erosion is major source of fine sediments (projects 1, 2, 3, 4, 6). 7. Erosion control alternatives (streambank and upland) are very expensive to implement (projects 6 and 7). 8. Existing erosion (streambank and upland) control measures are not capable of resolving sedimentation problem (project 6).	1. Increased control practices (upland and streambank) must be used on critical source areas. 2. New control alternatives (especially no-till) must be examined to determine feasibility. 3. Monitoring of critical source sediment must be continued and expanded to establish base-line data, identify critical areas, and determine results of implementation. 4. River corridor projects must be continued or created to reduce the impacts of sedimentation on backwaters. 5. Funding sources and authority for implementing control measures must be identified.	1. Accelerate existing upland erosion control practices. 2. Determine feasibility of no-till and other upland control. Conduct demonstration project at an identified critical source to monitor results. 3. Continue to evaluate streambank protection alternatives. 4. Continue Corps shoreline protection. 5. Follow up on streambank erosion inventory to identify and classify sites not inventoried. 6. Stabilize dredged material disposal sites. 7. Continue and expand tributary monitoring program. 8. Consider diking as an alternative to protect critical backwaters.

1 3

2. A study of the effects of the first tow of the navigation season on Lake Pepin water quality (1977).

3. A study of the effects of mechanical dredging and disposal on Boulanger Bend water quality (1977).

4. A literature review of the effects of navigation on water quality (1978).

5. Development of dredged material disposal management alternatives (1977-1978).

A detailed review of these activities is contained in later sections.

RECOMMENDATIONS

RATIONALE

The WQWG is aware that there are many important considerations related to the use and maintenance of the river for commercial transportation purposes. However, only water quality aspects were considered in the development of the recommendations that follow.

Some of the recommendations formulated by the work group are strongly protective of water quality. Primary reasons for this position are problems associated with: 1) the resuspension of potentially bioaccumulative contaminants; 2) the poorly understood nature of river sediments and sediment-water interactions; 3) the performance of channel maintenance during the seasons of greatest biological activity; and 4) the disposal of dredged material in locations of high biological activity. Preservation of water quality protects organisms dependent upon the riverine environment.

MANAGEMENT PRACTICES

Methods

1. To meet the intention of the Clean Water Act of 1977, site surveys and evaluations should be made at each site prior to dredging and disposal. Each site considered for dredging and disposal should receive individual consideration with respect to sediment and water quality impacts. Past studies in adjacent areas, existing information on local conditions, and site specific surveys should be considered. The Corps of Engineers should have the primary responsibility for these evaluations, with the assistance of State and Federal regulatory agencies.

2. Because of the potential for undetected contamination in dredged sediments, recommended methods of disposal to protect water quality are as follows:

   Alternative a. Removal of dredged material from the floodplain using hydraulic dredging. Since the hydraulic cutterhead creates minimal impacts and the disposal method would allow no resuspension during flooding, this alternative is the most protective of water quality.

   Alternative b. Complete containment of dredged material in a diked facility within the floodplain using hydraulic dredging. This method would minimize dredging impacts and allow no disposal site effluent. The disposal site would be subject to erosion during flooding.

Alternative c. Direct unloading of barges and removal of material from the floodplain using clamshell dredging. This method would have a greater dredging impact than hydraulic dredging, but material would have no potential for resuspension during flooding.

Alternative d. Direct unloading of barges and complete containment of material within the floodplain using clamshell dredging. This method would have some impacts from dredging as well as the potential for resuspension of material during flooding.

Alternative e. Containment of dredged material in a diked facility within the floodplain with a controlled effluent directed into the channel using hydraulic dredging. This method would minimize impacts from dredging and prevent violation of water quality effluent limits. The disposal site could be subject to erosion during flooding.

3. Criteria for sediment and water quality as they relate to dredging and disposal in the Mississippi River should be developed. These criteria should consider the incorporation of bulk sediment values, suspended particulate values, and elutriate test values. Until such criteria are determined, the following interim procedures should be followed:

a. Determine whether or not the sediments to be dredged are contaminated according to the "Work Guidelines for Sediment Classification" (EPA Great Lakes criteria).

b. If a determination as recommended in 3a. cannot be made for any reason, it should be assumed that the sediments have a potential for contamination and, therefore, should be treated as contaminated.

c. If sediment samples are found to contain 100 or more fecal coliforms per gram (dry weight), every reasonable effort shall be made to alert downstream users for a distance of 2 miles of the intention to dredge.

d. Known recreation areas (especially swimming areas) should be posted against primary contact recreation for a distance of 2 miles downstream both during dredging and for 24 hours after dredging operation.

4. After an adequate bottom sediment data base at frequently dredged locations is developed, such information should be used to determine the appropriate method of dredging and dredged material disposal.

5. Where contamination of bottom sediments to be dredged has been documented, the material should be disposed of in such a manner that it does not reenter the water.

6. Open-water disposal or beach nourishment should be considered as a disposal alternative by an interagency on-site inspection team only when current data show dredged materials to be free of contaminants, to consist of a coarse or sandy particle size, to be physically similar to existing disposal site material, and when no other more acceptable disposal alternative is available. Water quality effects, including bioassessment, of such disposal should be monitored until the acceptability or unacceptability of this practice is determined.

7. The Corps of Engineers should implement methods for restabilizing and revegetating diked disposal areas and historical disposal sites. Use of such methods will minimize resuspension by wind and floods, thus reducing future dredging and associated water quality problems.

8. The EPA should develop a list of all substances presently being transported or planned for transport on the river by barge which would significantly threaten the riverine environment if spilled. Further, alternative means of shipment of these hazardous materials should be considered.

9. State and Federal water quality regulatory agencies should emphasize and implement the goals of the Clean Water Act of 1977, especially Section 208. Proper management of the terrestrial boundaries of the river environment to alleviate nonpoint source pollution from agriculture and construction, reduce farmyard and landfill contamination, and improve wastewater treatment will promote more sophisticated management of the river main stem.

Monitoring

1. A strong effort should be made by the Corps to coordinate dredging related sediment and water quality sampling programs among agencies to minimize duplication of effort and improve the flow of information. Agencies to participate in this coordinated effort would include the Corps, USGS, SCS, EPA, and State and local environmental organizations.

2. Future studies to determine water quality impacts from dredging and disposal should emphasize the use of indicator parameters (total suspended solids, turbidity, iron, manganese, chemical oxygen demand, reduction-oxidation potential), water quality standards parameters (fecal coliforms, dissolved oxygen, temperature, pH) and toxic substance scans (metals and organics). Discrete water samples, correlation analysis between selected parameters, and reliable flow data are also emphasized as effective methods for determining water quality impacts. Future studies should spring from information already learned and should include long- and short-term monitoring of impacts.

DEVELOPMENT OF STANDARDS AND CRITERIA

1. A coordinated effort should be made by the States adjacent to the Mississippi River to develop compatible water quality management regulations, including uniform water quality standards.

2. States should develop regulations for the control of dredging and dredged material disposal activities so that these activities will not violate water quality standards. Development of such regulations should take into account mixing zones, ambient water quality fluctuations during the dredging season, "Quality Criteria for Water" (EPA), effluent limits applying to the disposal site, state-of-the-art information on dredging and disposal operations and effects, and river uses.

RESEARCH NEEDS

1. Research on dredging and disposal should focus on prediction of water quality impacts so that effective standards and criteria can be developed and implemented. Research should be conducted on known areas of contaminated sediments; sites of frequent dredging; and methods of analysis and prediction, such as bioassays on local flora and fauna and the elutriate test. This work should be performed as a part of normal Corps operation and maintenance costs and should be conducted by personnel from the Corps and other State and Federal regulatory agencies.

2. The need for environmentally sound dredging and disposal techniques requires that the present art of dredging and disposal be elevated to a scientific discipline. Funding and supervision by the Corps should be directed toward determining the environmental impacts caused by the physical aspects of dredging and disposal operations. Such physical aspects as types of dredge used, disposal techniques, and sediment particle size need to be examined in detail so that increased knowledge in these areas can be correlated with existing knowledge on water and sediment interactions. The development of new models and testing of existing models, such as those of the Waterways Experiment Station, should be conducted as a means of predicting impacts on water quality. Since the literature indicates that impacts from dredging and disposal appear to be very site-specific, even within a limited geographic area, site-specific information on the Upper Mississippi River is needed to make general predictions and policies.

DREDGING AND DREDGED MATERIAL DISPOSAL

PROGRAM AND POLICIES

Maintenance of a 9-foot navigation channel and operation of the locks and dams on the Upper Mississippi River are Federal activities

conducted by the Corps and authorized by the River and Harbor Act of 1930 and other statutes. As part of these operation and maintenance projects, the Corps performs annual maintenance dredging of the navigation channels to remove accumulated sediments which prevent safe vessel passage. Traditionally this dredged material has been deposited in marshy areas along the river shoreline, on land, and in the main stream or open water. The disposal method has depended on the type of equipment available, the amount and nature of material to be dredged, the distance from the dredging site to the disposal site, the geographical setting, and the economics of the operation.

In more recent years, the effects of dredging and disposal on environmental quality have become an important issue. Legislation to protect environmental resources has also resulted from this concern. The Corps was required, in keeping with the National Environmental Policy Act, to prepare a detailed environmental impact statement (U.S. Army Corps of Engineers, 1974) concerning operation and maintenance of the 9-foot channel, since these activities constitute a major Federal action significantly affecting the quality of the human environment. Significant conclusions of this study were that dredged material disposal islands were eroding, dredged material was destroying aquatic habitat and organisms, and turbidity was generated by channel maintenance activities.

Currently, the disposal of dredged material must comply with the National Environmental Policy Act of 1969, the Federal Clean Water Act of 1977, the Fish and Wildlife Coordination Act of 1958, and other statutes which take into account wetland protection, fish and wildlife, recreation, and navigation.

In addition to these statutes, Section 404(t) of the Clean Water Act of 1977 provides for the safeguarding of water quality during the disposal of dredged material. Under this statute, disposal of dredged material must comply with the same effluent and water quality standards and the same procedural requirements governing any other discharge to the Nation's waters. These requirements allow no open water disposal

of dredged material and dictate compliance with applicable effluent limitations of any effluent from disposal systems designed to treat dredged material. Therefore, the polluting character of dredged material has come to play an important role in deciding where deposition is to take place and what type of equipment is to be used.

Under Section 404(t) of the Clean Water Act of 1977, the States were given the authority to govern the disposal of dredged material in navigable waters. In the future, the States will develop standards applicable to the disposal of dredged material. The standards are to be based on interim guidelines developed by the EPA in conjunction with the Department of the Army (Environmental Protection Agency, 1975). The interim guidelines provide that:

> "In evaluating whether to permit a proposed discharge of dredged or fill material into navigable waters, consideration shall be given to the need for the proposed activity, the availability of alternative sites and methods of disposal that are less damaging to the environment, and such water quality standards as are appropriate and applicable by law."

Interim guidelines for evaluating impacts were published by the U.S. Army Engineers Waterways Experiment Station (1976) and include detailed procedures for conducting an elutriate test, estimating mixing zones, performing bioassays, conducting total sediment analyses, and evaluating the biological community structure. These guidelines do not designate any hard and fast test which dictates disposal site selection because no tests will predict impacts over a broad range of sites. However, they do attempt to provide a balance between the technical state of the art and routinely implementable guidance for the procedures specified in the Federal Register until a permanent procedures manual can be developed.

The present policies of the States in regard to dredged material disposal are interim until applicable standards can be developed by the Corps and EPA. Under section 30.12 of the Wisconsin Statutes, open

water disposal of dredged material, including beach nourishment, is totally prohibited. All disposal in Wisconsin must occur above the normal high-water mark. In addition, a discharge permit is required under section 147.025 of the Wisconsin Statutes for the discharge of dredged materials into State waters. At present, Minnesota has no regulations specifically governing dredged material disposal; however, open-water disposal in State waters is not allowed without a permit. Minnesota also requires that any effluent generated from dredging operations meet the standards and regulations described in Minnesota Statutes, Chapters 115 and 116, as amended, and that the effluents generated from disposal and dredging operations be monitored for their impacts on water quality. Iowa Statutes dictate that beach nourishment and open-water disposal are not allowed unless a discharge permit is obtained from the State. Iowa does not require a permit for discharge of effluent from a diked disposal facility, but impacts of the effluent can be regulated by State water quality standards. Placement and disposal of dredged material are currently subject to approval from an interagency on-site inspection team (which includes State representatives) organized and implemented by GREAT I.

Much of the concern over Corps dredging and disposal operations is directed toward the environmental impacts of dredged material placed in open water and of return water from diked disposal facilities. This concern includes practices of beach nourishment, effluent overflow from diked disposal areas, main channel or open-water disposal, and island creation. Examples of the major adverse impacts on water quality from dredging and disposal are included in the following list. These effects were documented in research studies conducted throughout the United States.

- Increased turbidity and reduced light penetration.

- Changes in streamflow characteristics as a result of changes in bottom topography.

- Subsequent erosion of dredged material from disposal sites by wind and water.

- Exposure of sediment materials which have a high biochemical and chemical oxygen demand.

- Reductions in dissolved oxygen.

- Possible release of toxic metals, pesticides, hydrocarbons, nutrients, and pathogens.

- Reductions in pH.

It should be stressed that the presence or absence of these impacts is highly dependent on the material dredged, the type of methods used in the dredging and disposal operation, and the ambient water characteristics. Impacts may also vary considerably from site to site and season to season. In order to further the scientific discipline of dredging and disposal impacts, data must be gathered on individual projects. Without site-specific information, an effective level of resolution cannot be gained and broad applicable management policies cannot be implemented. Quantitative information on all aspects of dredging and disposal impacts is presently being gathered, but evaluation of this information still remains largely an art. A summary of available research information is provided below.

STUDIES IN THE UNITED STATES AND OTHER COUNTRIES

Research concerning the environmental impacts of dredging and disposal activities dates back as far as the 1930's and 40's (Morton, 1977). However, it was not until recent legislation provided the impetus for research that a significant body of this knowledge has

been accumulated. Literature reviews (Lee et al., 1975; Morton, 1977) have summarized available information and identified problem areas related to evaluation of impacts. A description of many of these research studies follows, including a discussion of major conclusions from each one.

Water Quality Impacts From Dredging

Results from a study in the Arthur Kill tidal channel, New Jersey, in which highly polluted sediments were dredged with a clamshell bucket, indicated increased turbidity and decreased oxygen levels during dredging. Decreases up to 80 percent of ambient dissolved oxygen levels were attributed to resuspension of bottom sediments (Brown and Clark, 1968).

The physical impacts of dredging and disposal were studied by Sustar et al. (1976) in San Francisco Bay. The authors concluded that the actual intensity, duration, and area influenced by sediment-water interactions are often much greater during open-water disposal than during dredging. Increases in solids levels during dredging are confined basically to the channel, whereas increases at disposal sites often influence areas outside the site boundaries. Both operations have very little effect on the upper water column, and increases in solids concentrations typically did not exceed levels occurring during storms. In a comparison of equipment impacts, grapple or clamshell dredging produced the highest levels of turbidity and suspended solids in the water column, while hydraulic dredging produced the lowest levels. The degree and duration of interaction, type of equipment and operation used, and site conditions all affect the nature of sediment water interactions.

Information from Herbich (1975) indicates that dredging can have advantageous effects on the aquatic environment by removing polluted bottom sediments for safe storage and/or treatment, reoxygenating sediments and the water column through mixing, resuspending nutrients making them available to suspension feeders, and removing dissolved and particulate pollutants from the water column by adsorption and resettling. Typical deleterious effects such as loss of habitat and resuspension of pollutants were also discussed.

Gustafson (1972) also detailed the beneficial effects of dredging. Bacteria attack sewage substances much more readily en the substances are attached to clay rather than dispersed within th water, as long as the clay remains suspended. Turbid waters also offer shelter and protection to larval and immature marine life which use bay waters as nursery grounds. Oertel (1975) found that disposal activities and associated turbidity at a beach nourishment site attracted amphipods and bottom feeding fish communities.

Yogi et al. (1976) conducted independent tests of hydraulic and mechanical dredges in Japan to determine design considerations for reducing turbidity. Increases in turbidity from a hydraulic dredge were largely dependent on the swing speed of the cutterhead and the dredging thickness of the cutterhead pass. Tests on grab bucket dredges indicated that open-type buckets created greater turbidity by a factor of 1.5 times than did closed-type buckets. Closed-type buckets were recommended for use in reducing turbidity.

To assess impacts from a hydraulic dredge, Smith et al. (1976) developed the concept of an "impact day" (effect of dredging over a 1-day period) based on Washington State Water Quality Criteria. Results showed that the most frequent impact day criterion exceeded was turbidity, followed by pH and dissolved oxygen. Seventy-five percent

of the sample sequences showed at least one parameter "impacted" by dredging. Sulfide concentrations in bottom waters near the cutterhead were higher than ambient levels on several days and reached as high as 1,690 ug/l (micrograms per liter) in one sample.

Water Quality Impacts From Disposal

Comprehensive field studies to determine impacts from dredging and disposal on physical, chemical, and biological characteristics of the Chesapeake and Delaware Canal in Maryland were conducted as early as 1965 (Chesapeake Biological Laboratory, 1970). The physical-chemical studies concluded that turbidity increased over an area of 1.5 to 1.9 square miles (4 to 5 square kilometers) around the open-water disposal site; however, the suspended sediment load over most of the area was within the range of natural variation during all seasons. Suspended sediments near the surface were carried in a tide-related plume up to 3.1 miles (5,000 meters) from the disposal site, while material deposited on the bottom covered an area at least 5 times as large as that of the defined disposal site. Water column effects usually disappeared within 2 hours after pumping stopped. Total phosphate and nitrogen were increased in the immediate vicinity of the discharge by factors of about 50 and 1,000, respectively, over ambient levels. Little or no oxygen sag was evident in the discharge plume.

Much of the research on freshwater impacts from dredging and disposal has been conducted in the Great Lakes because of the large number of harbors and channels requiring maintenance dredging. The Corps (1969) compiled a report on several studies which monitored impacts from dredging and disposal. The use of clamshell, hopper, and hydraulic dredges along with disposal in open-ended basins, closed basins, and open water yielded widely differing results. Water quality impacts from hopper dredges and disposal areas were reflected in increases

in turbidity, suspended solids, oil and grease, ammonia nitrogen, total and organic nitrogen, total phosphorus, volatile solids, chemical and biochemical demand, conductivity, alkalinity, and iron as well as decreases in dissolved oxygen. In some cases, no significant changes in water quality were noted, especially near clamshell dredging and outside of containment dikes.

In a study of hydraulic dredging and disposal in the mouth of the Maumee River at Toledo, Ohio (Krizek et al. 1976), the water quality of the surrounding region was evaluated and the fate of pollutants during the dredging and disposal cycle was assessed. The use of a diked containment facility significantly improved the quality of the dredged slurry so that effluent was similar in quality to ambient river water. Apparently contaminants were associated closely with solid particles and settled out rapidly in the diked area. However, the quality of groundwater was slightly worse near the diked facility than either the river water or the effluent water as a result of leaching of the disposal material.

Another study dealing with disposal of Great Lakes sediments (Jin et al. 1977) found that the leachates of dredged materials placed with or without chemical additives in diked containment areas do not appear to cause any serious pollution problems, largely because the permeability of most clayey silt dredged materials is very low. Added factors that will serve to minimize the pollution potential of any dredged material leachates are the natural ability of the soil to remove many contaminants and the ability of the groundwater to dilute the relatively small amounts of contaminants that are leached from the solids.

Sly (1977), in studies on Lake Erie and Lake Ontario, showed that levels of total and reactive phosphorus along with turbidity, nutrients,

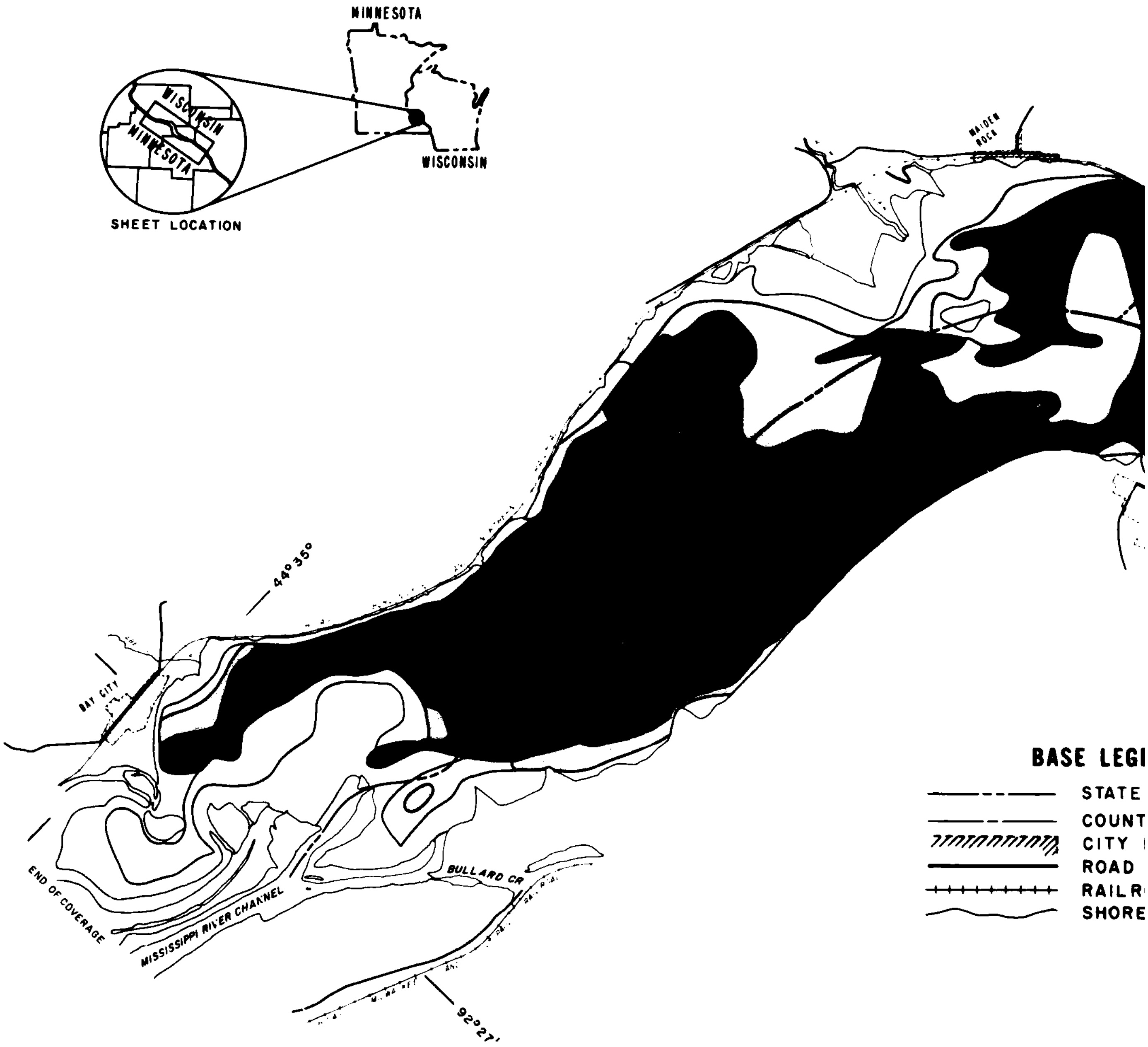
and heavy metals increased rapidly at both the dredging and open-lake dumping sites. However, elevated concentrations decreased rapidly, and background conditions in overlying waters were generally reestablished within a few hours because of particle settling, dilution, and sorption reactions. With the exception of iron and phenols, all measured water quality parameters fell within Canadian drinking water standards at the study sites.

O'Neal and Sceva (1971) summarized studies from several rivers and harbors in the northwest United States. They observed that disturbance of bottom materials by hydraulic pipeline and grapple dredging and the discharge of dredged materials can significantly reduce dissolved oxygen levels, cover or smother bottom organisms, release toxic compounds in localized areas, and produce visible turbidity plumes. They also concluded that development of a healthy biological population of benthic organisms is inhibited when the volatile solids content of dredged bottom sediments deposited in open water is 10 percent or higher.

Markey and Putnam (1976) reported on the effects of maintenance dredging on selected parameters in the Gulfport Ship Channel, Mississippi. Turbidities and suspended solids were measured, and the size and dispersion of the discharge plumes were defined. Distributions and levels of bacteria and heavy metals were studied to determine the extent of the release of these materials from the sediment to the waters. The biological parameters investigated were coliform bacteria, plankton, and benthic invertebrates. It was found that dredging had no significant or long-range effect on any of the conditions evaluated in this investigation.

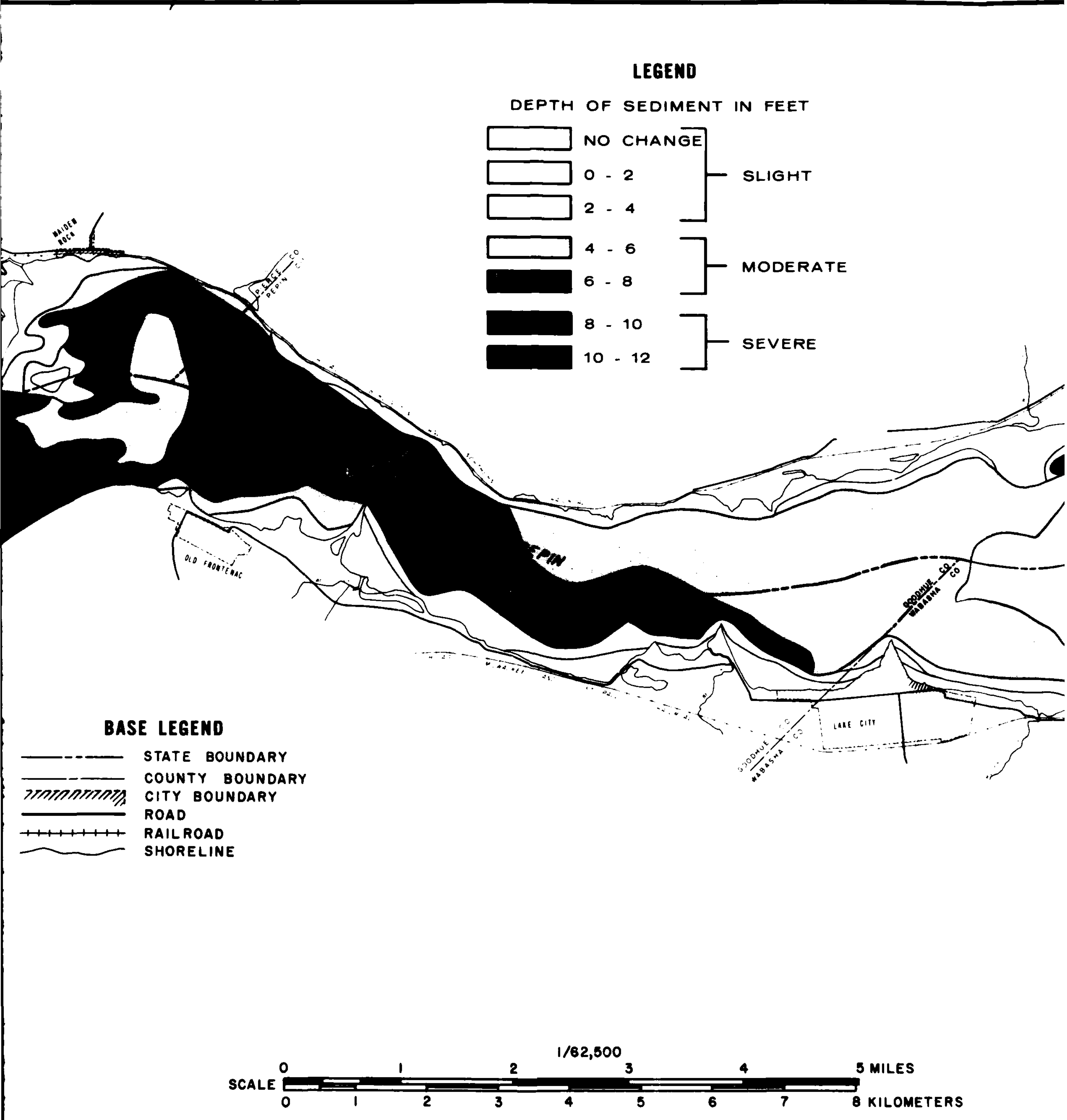
That no major unexpected changes occurred in the water column, the organisms, or the sediments which can be solely attributed to open

U. S. DEPARTMENT OF AGRICULTURE



SOURCE:
SCS DRWG. NO. 5,P-36,862 (5-78) AND
INFORMATION FROM FIELD TECHNICIANS
PROJECTION UNKNOWN

USDA-SCS-LINCOLN NEBR 1978



LEGEND
DEPTH OF SEDIMENT IN FEET
NO CHANGE
0 - 2
2 - 4
SLIGHT
4 - 6
6 - 8
MODERATE
8 - 10
10 - 12
SEVERE
OLD FRONTENAC
GOODHUE CO
WABASHA CO
LAKE CITY
BASE LEGEND
STATE BOUNDARY
COUNTY BOUNDARY
CITY BOUNDARY
ROAD
RAILROAD
SHORELINE
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SCALE
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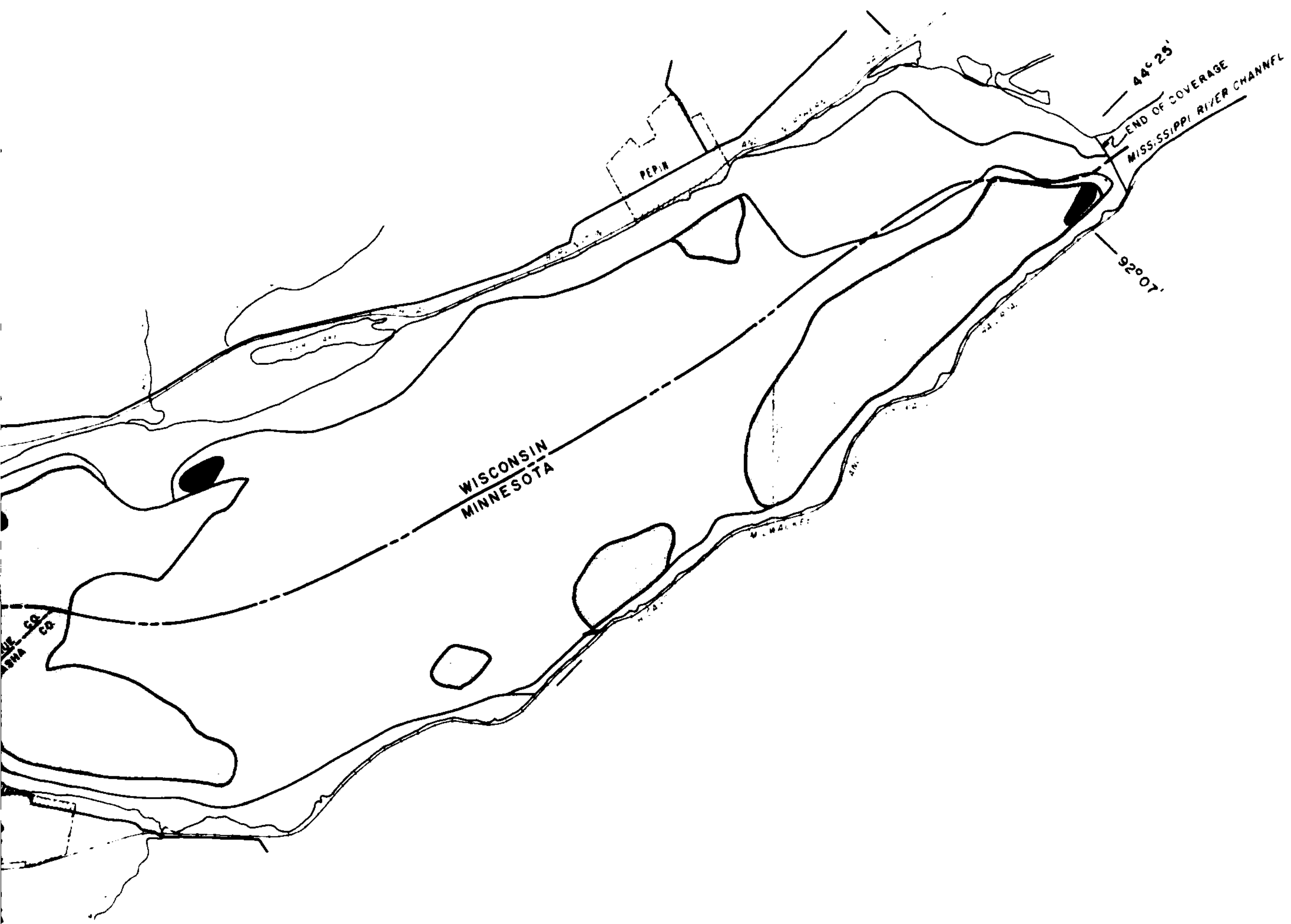
0 1 2 3 4 5 6 7 8 KILOMETERS



SEDIMENTATION OF

LAKE PEPIN FROM 1895 TO 1976

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA AND WISCONSIN

ERS

9-15-78

5,P-37,062.1

water dumping activities was also the main conclusion reached by the National Marine Fisheries Service (1975) in a study near New London, Connecticut. Increases in total organic carbon and suspended solids along with decreases in dissolved oxygen and pH were noted in the immediate vicinity (150 meters) of the dump site, but parameter levels usually returned to background within a matter of minutes, especially in surface waters.

Extensive field and laboratory investigations to ascertain the effect of dredging and disposal operations on water quality and biota have been performed in San Francisco Bay. Wakeman (1976) documented increases in suspended solids, decreases in dissolved oxygen, and releases of trace elements, chlorinated hydrocarbons, and nutrients with considerably less severe impacts near the dredging operation and in the upper water column than in the lower water column and near the disposal site. Releases of contaminants were lower under oxidizing conditions and from coarser sediments. Laboratory tests on benthic organisms demonstrated that the effects of increased suspended solids and reduced dissolved oxygen may combine to increase mortality. Dilution of disposal material was seen to be an important mechanism in reducing impacts.

Results of water quality studies conducted at dredging sites in the southeastern United States (Windom, 1972) indicated several preliminary findings which have been confirmed by subsequent studies. In natural or relatively unpolluted areas, dredging had no significant effect on water quality whether diked or undiked confinement techniques were used, while dredging of polluted sediments did not necessarily impair water quality. Where water quality was impaired, the impacts generated by dredging and disposal did not necessarily bear any simple

relation to the composition of dredged sediments. The author concluded that, to evaluate the possible effects on water quality of dredging sediments in a particular area, specific information must be obtained in that area, depending on its characteristics. The length of time the dredged slurry is allowed to remain in the disposal area will greatly influence the quality of the effluent.

Research has also been conducted to determine alternative methods for treatment of dredged material. Currently, the simplest and most widely used method of alleviating water quality impacts from disposal activities is the use of dikes to contain dredged material. In addition, various methods, used in conjunction with diked facilities or without them, have been discussed by Krizek et al. (1976); Moore and Newbry (1976); Morton (1977); and Wang et al. (1977). Besides improving existing practices (such as dredging during darkness to minimize impacts on photosynthesis), modifying equipment, and educating operators about environmental concerns, various treatment alternatives are available. Physical processes which separate sediment from water include screening, centrifugation, natural sedimentation, filtration through sand or carbon, vacuum and pressure filtration, aeration, and porous dikes. Chemical processes which may be used include flocculation or polymerization, adsorption filtration, electrodialysis, chemical oxidation, and foam separation. Biological processes, such as trickling filters and vegetation uptake, are also feasible, but have much lower potential for large-scale use than physical or chemical systems.

Dredged Material Research Program

Much of the research on environmental impacts from dredging and disposal has been conducted under the Dredged Material Research Program initiated by the Waterways Experiment Station in Vicksburg, Mississippi. This program, which began in 1973, has funded $30 million

worth of research relating to dredging and disposal. Although almost all of this work has dealt with coastal and estuarine environments in the United States, results and recommendations can still be applied to dredging and disposal in the Midwest. The four major phases of this research have been: environmental impact and criteria development, habitat development, disposal operations, and productive uses. A complete bibliography of reports published by the program is available from the Waterways Experiment Station in Vicksburg. Results have been summarized below, particularly as they relate to water quality.

Environmental Impact and Criteria Development. - Research has indicated that some of the chemicals disturbed during dredging and disposal may be dissolved or released in the water column, thus becoming more readily available to organisms. Most chemicals, however, remain attached to or associated with sediment particles and become incorporated in the sediment again as settling occurs. Site studies have observed releases of orthophosphorus, ammonia, manganese, iron, and reactive silica. Water quality conditions usually return to ambient within a few hours. Reduced dissolved oxygen levels and increased suspended sediment levels have also been observed, although they also return to ambient levels within a short time. No release of chlorinated hydrocarbons or petroleum hydrocarbons in the dissolved state has been observed. Generally, the more disturbed the bed material, the greater the potential for release of contaminants.

Bioassay studies using marine, estuarine, and freshwater organisms have shown that lethal concentrations of suspended dredged material are much higher than those observed in actual dredging and disposal activities. Benthic organisms were usually able to recover from or recolonize a disturbed area within a short time (3 months to 3 years). Uptake of contaminants by organisms was minimal in tests conducted. Models to predict the extent and configuration of plumes and bioassays to determine impacts on organisms have been developed for implementation in site-specific studies.

Habitat Development. - Studies have indicated the potential for development of new wetland habitats as well as impacts on existing wetlands from dredged material deposition. Nutrient and heavy metal cycles were evaluated for marshland ecosystems affected by dredged material disposal. Several salt marsh plant species showed significant potential for accumulation of heavy metals, while others did not.

Disposal Operations. - Guidelines and design considerations for effective construction of diked areas and containment of dredged material have been developed. Effluent quality can be improved through use of mechanical (pervious dikes, trenching, oxygenation, polymers) and biological (vegetation) systems. Natural vegetation was demonstrated as an effective filter and mechanism for nutrient removal, but significant amounts of heavy metal contamination cannot be removed by this method.

Productive Uses. - Dredged material has been used productively for abandoned pit or strip mine reclamation, sanitary landfill cover, and shrimp production. Marketing of dredged material in these ways can help recover transportation costs.

STUDIES IN THE UPPER MISSISSIPPI RIVER BASIN

A Corps study in pool 8 (1974) showed that turbidity generated during maintenance dredging spread beyond the disposal site and persisted longer than the dredging and disposal period itself. Turbidity during dredging was double ambient levels. Nitrate and nitrite showed significant increases during dredging, while dissolved oxygen showed a significant decrease.

In another Corps study (1973), a clamshell dredging operation was monitored near the mouth of the Minnesota River. Turbidity tripled

100 feet downstream of the dredge. Although surface turbidities returned to ambient levels 0.8 mile downstream, bottom turbidities remained elevated.

The MPCA (1975a) studied the effects of hydraulic dredging on water quality below lock and dam 6 near Richmond Island. Turbidity and suspended solids levels exceeded State effluent standards in the disposal island runoff. Mercury, oil, pH, fecal coliform, and PCB's (polychlorinated biphenyls) also were affected by dredging and disposal, but the study concluded that major degradation of the Mississippi River below the operation was not evident.

The MPCA (1975b) also monitored impacts from clamshell dredging near Grey Cloud Island in pool 2. Below the operation, increases were observed for suspended solids, turbidity, BOD_5 (5-day biochemical oxygen demand), zinc, and iron. Suspended solids, turbidity and zinc levels returned to background within one-quarter mile downstream, but BOD_5 and iron had not returned to background within 1 mile below the operation. No significant local changes in water quality were indicated.

Lee (1977) conducted a hydraulic dredge monitoring study in conjunction with the GREAT (1978) monitoring study at Grey Cloud Slough in pool 2. Iron, manganese, zinc, and arsenic were present in highest concentrations in the sediment, while iron, manganese, and nickel showed the most significant release in elutriate tests. Concentrations in the disposal discharge were, in general, comparable with those in the elutriates. Organic nitrogen showed a potential for release in elutriates, but soluble orthophosphate indicated a potential for uptake. Concentrations of nitrogen and phosphorus compounds in the disposal plume showed few patterns. Turbidity returned to background within a few hundred meters of the discharge. Resuspension of sediments caused no noticeable decrease in dissolved oxygen levels.

The Metropolitan Council (Oberts, 1978) has provided a valuable summarization and assessment of adverse water quality impacts from dredging and disposal for the St. Paul-Minneapolis area. The report details environmental considerations as well as physical and chemical impacts on water quality resulting from current dredging and disposal practices. Most pollution appears to be short-term and localized. Remedial programs and methods to minimize impacts are also discussed.

Cursory examinations of methods for miminizing disposal impacts from hydraulic dredging operations were performed by Claflin (1976). Use of a silt screen downstream from a disposal island in pool 2 succeeded in decreasing average turbidity from 33.1 NTU (nephelometric turbidity units) with no screen in place to 27.3 NTU while the screen was in place. The author did not believe the silt screen effectively reduced the settling of finer particulate material.

In another section of the report, the author discussed the addition of polymers to disposal material in pool 8 as a means of inducing settleability. The polymer injection did not appear to have any effect on turbidity levels in the runoff effluent, possibly because of the erratic nature of the effluent itself.

GREAT I WATER QUALITY WORK GROUP STUDIES

Grey Cloud Island (1976)

A comprehensive monitoring study to measure short-term water quality impacts from a hydraulic dredging and disposal operation was carried out in July 1976 by the WQWG (GREAT 1978(a)). The study site was chosen in order to measure impacts in a highly contaminated reach of the Mississippi River. It was located downstream of the Minneapolis-St. Paul area and the Metropolitan Treatment Plant in pool 2. Turbidity and suspended solids returned to background levels within 1 mile downstrear

of the disposal island. Chemical and biological parameters were closely correlated with turbidity and suspended solids, and generally returned to background within a short distance of the disposal runoff. (Results compared closely with those of the MPCA (1975b) study near this site, with the exception of BOD_5 which, during the GREAT I study, returned to background within 1 mile downstream of the disposal operation.) Most parameters increased in concentration from above to below the dredging and disposal operation, but ambient fluctuations in the river water were, in many cases, greater than impacts caused by dredging and disposal.

Proposed MPCA water quality standards for arsenic, chromium, lead, mercury, manganese, PCB's, and suspended solids were exceeded only in a limited area immediately downstream of the disposal runoff. Impacts were generally localized because of the sorptive capacity of rapidly settling resuspended sediment particles and dilution. Detection of high or low concentrations of a given parameter in the sediment did not necessarily dictate a corresponding level of concentration in the water receiving the dredged material runoff. It was postulated that concentrations of contaminants in the sediment were influenced by seasonal fluctuations in flow, sediment deposition, and water quality.

Various sampling techniques were also assessed as part of the study design. It was concluded that a correlation analysis of parameters and the examination of discrete water samples provided the best analysis of impacts created by dredging and disposal.

Boulanger Bend (1977)

A study to monitor the short-term impacts of a clamshell dredge on water quality was conducted in July 1977 by the WQWG (GREAT, 1978 (b)). The study site was located several miles downstream from the Grey Cloud Island study site in pool 2. Turbidity levels returned

to background within 1,000 feet downstream of both the dredging and disposal operations, and impacts lasted only 1 to 2 hours. The lack of strong correlations between physical (turbidity, suspended solids) and biological-chemical parameters was attributed to the narrow range of concentrations encountered in the plumes and the spatially erratic nature of the plume resulting from intermittent dredging and disposal activities, barge influences, and other factors.

Near-bottom concentrations of most parameters were higher than surface concentrations in the dredging and disposal plumes because the resuspended material settled rapidly and migrated along the bottom as a density current. The disposal plume created greater overall impacts and released more contaminants than the dredge plume and was associated with greater agitation of the dredged material, lower dissolved oxygen conditions, lower pH, and less mixing and dilution potential.

In some plume samples, proposed MPCA water quality standards were exceeded for iron, mercury, ammonia, turbidity, dissolved oxygen and fecal coliforms. But in many cases ambient levels of these parameters were already in excess of standards. As in the Grey Cloud Island study, detection of a given component in the sediment to be dredged did not dictate its presence in corresponding concentrations in the dredging and disposal plumes.

The use of aerial-color and color-infrared photography as a monitoring technique was viewed with mixed reactions. Although it effectively documented the extent of surface turbidity plumes and the position of sampling boats, it could not predict overall water column impacts since relatively poor correlations were observed between bottom and surface concentrations of parameters.

NAVIGATION

PROGRAM AND POLICIES

Since the inception of the 9-foot navigation project on the Upper Mississippi River in the 1930's, the transportation of goods and commodities on the river has become an increasingly integral part of the economy of the Midwest. The popularity of recreational and pleasure craft has also grown at a rapid rate and placed an additional demand on the river resource.

Commercial transportation on navigable waters is currently regulated by the U.S. Coast Guard and the EPA (Code of Federal Regulations: Titles 33, 40, and 46). These regulations deal specifically with the shipment of hazardous and flammable materials, design of barges, periodic inspection of barges, marine sanitation devices, notification procedure in case of a spill, and so on. Currently, no laws exist which limit the shipment of certain materials or the size of towboat engines. Design and discharge of marine sanitation devices is also specified for recreational and pleasure craft.

Very little information exists on the impacts of navigation on water quality. Historically, the emphasis of navigation studies has been on the economic aspects of navigation. Not until recent interest and concern turned toward the environmental consequences of navigation has research begun in this area.

Probable impacts from commercial navigation and barge fleeting activities were addressed in an environmental impact assessment filed by the Corps in connection with the operation and maintenance of the 9-foot channel (U.S. Army Corps of Engineers, 1973). Research information concerning navigation impacts from commercial barges and recreational craft is described in the following section.

STUDIES IN THE UNITED STATES AND OTHER COUNTRIES

Cashin (1956), in a study near Port Lyttelton, New Zealand, analyzed bed material composed of 54 percent clay, 45 percent silt, and 1 percent fine sand. Tug propellers operating six fathoms (36 feet) above the bottom brought a trail of mud to the surface.

A laboratory modeling study performed at the Department of Civil Engineers, Queens University in Canada (Wilson, 1973), produced several significant findings. Research concluded that the most dramatic bed material disturbance caused by the passage of ships is from the wake zone; i.e., that disturbance caused by the action of the stream of high velocity water issuing from the propeller. The amount of bed erosion depends upon the velocity of the propeller, distance between the propeller and the bed surface, and properties of the bed material. Tests performed with fine Ottawa sand showed that passage of a freight vessel with a bottom clearance of 3 feet or less will disturb the channel bed to a depth exceeding 1 foot. Upstream-headed (against current) tows will create more bed erosion than downstream-headed (with current) tows at a comparable and constant speed.

In another Canadian study on the Great Lakes, Sly (1969) observed no discernible disturbance of bottom materials in water deeper than 4.5 meters (14.5 feet) below the axis of a tug propeller with a 1.3-meter (4.5-foot) blade and a draft of 1.9 meters (6 feet). At a clearance of 3.3 meters (10.5 feet) between prop and sediment, disturbance was induced to a depth of 2.0 centimeters (0.8 inch) in the sediment. A clearance of 2.0 meters (6.5 feet) disturbed bottom sediments down to 7 to 8 centimeters (3 inches). It was suggested that large vessels on the Great Lakes having drafts up to 8 meters (26 feet) and bottom clearances of 1 to 2 meters (3 to 6.5 feet) will significantly disturb bottom sediments to a depth approaching 0.5 meter (19 inches) over a path 2 to 3 times the width of the vessel.

A numerical model was developed by Liou and Herbich (1976) to determine sediment movement induced by ships. Once the speed of the ship, depth of the waterway, revolutions per minute and diameter of the propeller, and draft of the ship are given, the velocity distribution and the grain size of the initial motion could be obtained from this model. Case studies are presented to show the influence of significant factors associated with sediment movement induced by a ship's propeller.

In one of the few reports which has examined water quality impacts from boating activity, Yousef (1974) has indicated that agitation and mixing by motorboats could increase the turbidity and average particle size of suspended material throughout the water column. The increase in turbidity was generally dependent on water depth, motor power, and the availability and nature of sediment deposits. A decrease in turbidity was noticed 1 hour after boating ceased. However, changes in colloidal suspensions within the water columns have not been investigated. Increases in turbidity were accompanied by increases in organic carbon and phosphorus concentrations. Dissolved and particulate phosphorus seemed to increase in water samples collected after boating activity, at least on a temporary basis. Agitation and mixing by boating activity destratified the lake and, in some cases, increased oxygen concentration and the rate of oxygen uptake by suspended matter. Results for other parameters such as pH, specific conductance, temperature, and nitrogen were not conclusive. Long-term research is recommended.

STUDIES IN THE UPPER MISSISSIPPI RIVER BASIN

One of the most notable field studies on navigation impacts in the Midwest is that of Johnson (1976). During monitoring of barge tow passages at river mile 744.6 in pool 5, significant increases in parameters were noted at selected sites across the channel. Increases in

suspended solids levels ranged from 0 mg/l (milligrams per liter) in an adjacent side channel to 26.7 mg/l near the riverbank. Recovery times for return to ambient levels ranged from 50 to more than 165 minutes following passage. Turbidity generally followed trends similar to those observed for suspended solids, while dissolved oxygen revealed less dramatic decreases and faster recovery times. Multiple or successive barge tow passages observed in this study did not have additive effects on parameter levels, although studies at other sites did show additive effects. Correlation coefficients (r values) between suspended solids concentrations and turbidity units ranged from 0.65 to 0.75. Mean depth difference between tow drafts and channel bottom was 1.32 meters.

Link and Williamson (1976), conducting aerial remote sensing in conjunction with Johnson's study, also noted significant increases in suspended material concentrations following barge tow passage as well as trends in dissipation rates. It was apparent that the size of the plume generated by the passage of a tow was determined to a large degree by size of the tow and the clearance between the tow draft and channel bottom.

Karaki and von Hoften (1974) demonstrated through the use of aerial photography that barge tow traffic caused resuspension of sediments in the Illinois and Upper Mississippi Rivers. Sparks (1975) reported an increase in surface turbidity and a decrease in dissolved oxygen in the main channel of the Illinois River after barge tow traffic passed the study site. Both of these studies, however, failed to provide an adequate quantitative base from which conclusions could be drawn concerning a real extent of impacts, long-term impacts, and others.

Dr. Edwin Herricks (1978, personal communication) is presently conducting research on the impacts of barge traffic on the Kaskaskia River in Illinois. Research activities have been designed to answer questions regarding bottom scour, bank erosion, and water quality alterations resulting from barge tow traffic.

Results of a cursory field study near the mouth of the Minnesota River revealed turbidity impacts from barge traffic across a 300-foot cross section of the river (Corps of Engineers, 1973). Midchannel turbidity levels were approximately doubled immediately after a downstream-headed tow with four loaded barges passed the study site. Turbidity returned to ambient levels within 30 minutes after barge tow passage at the surface and after a somewhat longer period at the bottom.

GREAT I WATER QUALITY WORK GROUP STUDIES

Lake Pepin Study (1977)

A monitoring study was conducted in the early spring of 1977 in Lake Pepin, a natural lake within the Upper Mississippi River (GREAT, 1978(c)). The study confirmed existing information which has identified this area as a sediment trap. The silty clay sediment at the study site was found to contain a variety of contaminants including chromium, lead, manganese, mercury, zinc, nutrients, and PCB's.

The fine sediments were resuspended during the passage of the initial barge tow before ice cover had completely disappeared, but there was no evidence that contaminants were released into the water

column during resuspension. Impacts from the initial barge tow passage returned to ambient conditions, or nearly so, within 3 to 6 hours, apparently because of resettling and dispersion. Levels of pH decreased after initial passage, while other parameters, including suspended solids, increased.

Long-term impacts and subsequent impacts from additional barge tows were much less discernible than those from the initial tow. Possible mechanisms controlling natural as well as barge-induced behavior of parameters were discussed.

Navigation Effects Literature Search (1978)

A literature search was conducted by Ecology Consultants (1978) for the WQWG and Fish and Wildlife Work Group of GREAT I and the Upper Mississippi River Basin Commission. Abstracts are provided for 264 entries dealing with effects of navigation in inland waterways on the environment, including laboratory and field studies. An evaluation report and a detailed plan of study to fill information gaps are scheduled for future publication.

Several studies listed in the bibliography deal with discharge of wastes from watercraft in inland waterways (U.S. Federal Water Pollution Control Administration, 1967; Stokes, 1971; and Beszedits and Netzer, 1974). Design of treatment devices and treatment of wastes from various watercraft are discussed in addition to programs which may minimize impacts, such as installation of onshore handling facilities.

WATER QUALITY STANDARDS AND CONDITIONS

INTRODUCTION

Water is one of our most important resources. The uses to which water can be put depend upon the needs or desires of the user. In most cases, clean water is necessary to carry out these needs and desires.

Pollution of water degrades or destroys its value as a usable and beneficial resource. Man's activities can and do result in pollution of our waters.

The original purpose of the GREAT I WQWG was to assess the water quality impacts of dredging and other navigational activities on the Upper Mississippi River. However, public concern over other water quality problems and recent emphasis on water quality from Federal legislation created a need for the WQWG to deal with other water quality problems. Although the report up to this point has been directed toward assessing water quality impacts of dredging and shipping activities, this section attempts to address some of the public concerns about water quality.

In order to assess the effects of human activity on a specific body of water, it is necessary to look at the general background of the present water quality conditions, the designated uses to which the water is put, and the water quality criteria and standards developed to protect these uses.

WATER QUALITY CRITERIA

Water quality criteria, as the term is being used, mean designated concentrations of a constituent that, when not exceeded, will not harm an organism, organism community, or a prescribed water use. Water quality criteria are based on scientific data obtained from experimental or in situ observations that depict an organism's response to a defined stimulus or material under identifiable or regulated environmental conditions. They are not intended to offer the same degree of safety for survival and propagation at all times to all organisms within a given ecosystem. However, they are intended not only to protect essential and significant life in water and the direct users of water, but also to protect life that is dependent on life in water for its existence or that may consume (intentionally or unintentionally) any edible portion of such life. The criteria cited in this paper come from the EPA "Quality Criteria for Water," July 1976, pertaining to the classification given to the Upper Mississippi River (see table 2).

Table 2 - Federal Water Quality Criteria and State Water Quality Standards for the Upper Mississippi River from St. Anthony Falls, Minnesota, to Guttenberg, Iowa

Substance or Characteristic	Federal Criteria (1976)	Minnesota(1)	Wisconsin(2)	Iowa(3)
Aesthetic qualities	Water free from nuisance substance(4)	Water free from nuisance substance(4)	Water free from nuisance substance(4)	Water free from nuisance substance(4)
Alkalinity	Minimum of 20 as $CaCO_3$(a)			
Ammonia	0.02 as un-ionized ammonia(a)	$\frac{1.0}{1.5(a)}$ total		5(11/1 to 3/31)(a) 2(4/1 to 10/31)(a)
Arsenic	0.1(c)	0.05(b)		0.1(a)
Barium		1(b)		1(a)
Beryllium	0.011(a) soft 1.1(a) hard 0.1(c) continuous irrigation 0.5(c) neutral to alkaline fine textured soils			
Boron	0.75(c)	0.5(c)		
Cadmium (ug/l)	Cladocerans 0.4(a) soft 1.2(a) hard less sensitive species 4(a) soft 12(a) hard	10(b)		10(a)
Chlorine	0.01(a)			
Chlorides		100(b)		
Conductance-specific		1000 micromhos per centimeter(c)		
Chromium	0.1(a)(total)	0.05(a)(hexavalent)		0.05(a) (hexavalent
Fecal coliform bacteria	200/100 ml(a)(5)	200/100 ml(a)(5)	200/100 ml(a)(5)	200/100 ml(a)(6)

Table 2 (cont) - Federal Water Quality Criteria and State Water Quality Standards for the Upper Mississippi River from St. Anthony Falls, Minnesota, to Guttenberg, Iowa

Substance or Characteristic	Federal Criteria (1976)	Minnesota(1)	Wisconsin(2)	Iowa(3)
Color	Free from substances producing objectionable color (7)	Free from substances producing objectionable color	Free from substances producing objectionable color	Free from substances proing objectionable color
Copper	[0.1](a)	0.01 or 1/10 of 96-hour TLM(a)	•	0.02(a)
Cyanide	0.005(a)	0.2(b)		0.02(a)
Fluoride		1.5(b)		
Hardness		250(b)		
Iron	1.0(a)			
Lead	[0.01](a)	0.05(b)		0.1(a)
Mercury (ug/1)	0.05(a)			0.2(a)
Nickel	[0.01](a)			
Oil and grease	[0.01](a)	0.5 / 10(a) (8)		
Oxygen (dissolved)	5(a)	6(4/1 -5/31)(a) 5(all other times)(a) / 5(4/1 - 11/30)(a) 4(all other times)(a)	5(a)	5 for at least 16 hr/day - 4 at any one time(a)
Pesticides (ug/1):				
Aldrin/Dieldrin	0.003(a)			
Chlordane	0.01(a)			
DDT	0.001(a)			
Demeton	0.1(a)			
Endosulfan	0.003(a)			
Endrin	0.004(a)			

Table 2 (cont) - Federal Water Quality Criteria and State Water Quality Standards for the Upper Mississippi River from St. Anthony Falls, Minnesota to Guttenberg, Iowa

Substance or Characteristic	Federal Criteria (1976)	Minnesota(1)	Wisconsin(2)	Iowa(3)
Guthion	0.01(a)			
Heptachlor	0.001(a)			
Lindane	0.01(a)			
Malathion	0.1(a)			
Methoxychlor	0.03(a)			
Mirex	0.001(a)			
Parathion	0.04(a)			
Toxaphene	0.005(a)			
pH	6.5-9.0(a)	6.5-9.0(a) / 6.0-8.5(c)	6.0-9(a)	6.5-9.0(a) and no change greater than 0.5 units
Phenol (ug/1)	1(a)(9)	10(a)(9)		100(a)(9)
Phosphorous (ug/1)	0.1(elemental)(a)			
Phtalate Esters (ug/1)	3(a)			
Polychlorinated biphenyls	0.001(a)			
Radioactive material		(10)		
Selenium	[0.01](a)	0.01(b)		0.1(a)
Silver	[0.01](a)	0.05(b)		
Sodium		(11)		
Solids (dissolved)				750

Table 2 (cont) - Federal Water Quality Criteria and State Water Quality Standards for the Upper Mississippi River from St. Anthony Falls, Minnesota, to Guttenberg, Iowa

Substance or Characteristic	Federal Criteria (1976)	Minnesota(1)	Wisconsin(2)	Iowa(3)
Solids (suspended)	(12)			
Sulfide (hydrogen) (ug/l)	2(a)	20(d)		
Turbidity	Included with suspended solids	25		No increase by 25 NTU
Temperature	(13)	(14)	(14)	(14)
Unspecified toxic substances		(15)	(16)	(17)
Zinc	[0.01](a)			1

KEY:

All values in mg/l unless otherwise indicated.
Alphabetic footnotes - classification of use.

(a) Aquatic life and recreation (for Iowa also includes wildlife).
(b) Industrial consumption.
(c) Agricultural uses (for Minnesota also includes wildlife).
(d) Navigation and waste disposal.

Values in brackets are application factors used to multiply the LC_{50} value using sensitive resident species in determining local standards.

FOOTNOTES:

(1) Minnesota has different classification of use for different portions of the river. Area 1 standards are above the dividing line and Area 2 standards are below it. Area 1 is the stretch of the river from the St. Anthony Falls Upper Locks and Dam to the outfall of the Metro Wastewater Treatment Plant in St. Paul and from Lock and Dam No. 2 at Hastings to the Iowa border. Area 2 is the stretch of the river from the outfall of the Metropolitan Treatment Plant in St. Paul to lock and dam 2 at Hastings. Water quality standards will be maintained at all stream flows which are equal to or exceeded by 90 percent of the seven consecutive daily average flows of record (the lowest weekly flow with a once in 10-year recurrence interval) for the critical month(s).

(2) The standards shall apply at all times except (a) during periods when flows are less than average minimum 7-day low flow which occurs once in 10 years (7-day Q_{10}), and (b) in channels which convey a treated effluent to neutral surface water. In determining the 7-day Q_{10} flow, consideration will be given to streams subject hydraulically altered flow regimes.

Table 2 (cont) - Federal Water Quality Criteria and State Water Quality Standards for the Upper Mississippi River from St. Anthony Falls, Minnesota, to Guttenberg, Iowa

(3) Standards for chemical constituents are not to be exceeded when flow is equal to or greater than the 7-day Q_{10} flow unless from uncontrollable nonpoint sources.

(4) Nuisance substances are those that:

Settle to form objectionable deposits.
Float or debris, scum oil, or other matter.
Produce objectionable color, odor, taste, or turbidity.
Injure or are toxic or produce adverse physiological responses in humans, animals, or plants.
Produce undesirable or nuisance aquatic life.

(5) Based on a minimum of 5 samples taken over not more than a 30-day period. Fecal coliforms shall not exceed a geometric mean of 200 per 100 ml, nor shall more than 10 percent of the samples during any 30-day period exceed 400 per 100 ml.

(6) From 1 April through 31 October, fecal coliform content shall not exceed 200 organisms/100 ml, except when the waters are materially affected by surface run-off; but in no case shall fecal coliform levels downstream from a discharge which may contain human pathogens be more than 200 organisms/100ml higher than the background level upstream from the discharge.

(7) The source of supply should not exceed 75 color units on the platinum-cobalt scale for domestic water supplies; and increased color (in combination with turbidity) should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life.

(8) In addition, none in such quantities as to (a) produce a visible color film on the surface, (b) impart an oil odor to water or an oil taste to fish and edible invertebrates, (c) coat the banks and bottom of the watercourse or taint any of the associated biota, or (d) become effective toxicants according to the criteria recommended.

(9) None that could impart odor or taste to fish flesh or other freshwater edible products.

(10) Radioactivity is not to exceed the lowest concentration permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority

(11) 60 percent of total cations or milliequivalents per liter.(c)

(12) Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life.

(13) For any time of year, there are two upper limiting temperatures for a location (based on the important sensitive species found there at the time):

1. One limit consists of maximum temperature for short exposures that is time dependent and is given by the species-specific equation:

Temperature (^{o}C) = $1/b(\log_{10}(\text{time in minutes})-a)-2$
Where:
a = intercept on the "y" or logarithmic axis of the line fitted to experimental data which are available for some species from Appendix II-C, NAS, 1974.
b = slope of the line fitted to experimental data which are available for some species from Appendix II-C, NAS, 1974.

Table 2 (cont) - Federal Water Quality Criteria and State Water Quality Standards for the Upper Mississippi River from St. Anthony Falls, Minnesota, to Guttenberg, Iowa

2. The second value is a limit on the weekly average temperature that:

a. In the cooler months (mid-October to mid-April) will protect against mortality of important species if the elevated plume temperature is suddenly dropped to the ambient temperature, with the limit being the acclimation temperature minus 2^{o} C when the lower lethal threshold temperature equals the ambient water temperature (in some regions, this limitation may also be applicable in summer).

b. In the warmer months (April through October) is determined by adding to the physiological optimum temperature (usually for growth), a factor calculated as one-third of the difference between the ultimate upper incipient lethal temperature and the optimum temperature for the most sensitive important species (and appropriate life state) that normally is found at that location and time.

c. During reproductive seasons (generally April through June and September through October) meets site specific requirements for successful migration, spawning, egg incubation, fry rearing and other reproductive functions of important species. These local requirements should supersede all other requirements when they are applicable.

d. Is a site-specific limit that is found necessary to preserve normal species diversity or prevent appearance of nuisance organisms.

(14) The standards for each State are explained below:

MINNESOTA

The temperature limit is 5^{o} F above natural in streams, based on a monthly average of the maximum daily temperature. However, in no case shall it exceed the daily average temperature of 86^{o} F for Area 1 or 90^{o} F for Area 2 (see footnote 1). In addition, the temperature criteria in table 1 (below) will be applicable for the Mississippi River from lock and dam 2 at Hastings to the Iowa border and from St. Anthony Falls upper lock and dam to the outfall of Metropolitan Wastewater Treatment Plant at Pig's Eye (based on weekly average temperature). The temperature criteria in table 2 (below) will be applicable to the Mississippi River from the outfall of the Metropolitan Treatment Plant at Pig's Eye to lock and dam 2 at Hastings (based on weekly average temperature).

WISCONSIN

a. There shall be no temperature changes that may adversely affect aquatic life.

b. Natural daily and seasonal temperature fluctuations shall be maintained.

Table 2 (cont) - Federal Water Quality Criteria and State Water Quality Standards for the Upper Mississippi River from St. Anthony Falls, Minnesota, to Guttenberg, Iowa

c. The maximum temperature rise at the edge of the mixing zone above the existing natural temperature shall not exceed 5° F for streams and 3° F for lakes.

d. The temperature shall not exceed 89° F for warmwater fish.

In addition to the above standards for fish and aquatic life, the monthly average of the maximum daily temperature in the Mississippi River outside the mixing zone shall not exceed the limits in table 1.

IOWA

No heat shall be added to the Mississippi River that would cause an increase of more than 5° F. The rate of temperature change shall not exceed 2° F per hour. In addition, the water temperature at representative locations in the Mississippi River shall not exceed the maximum limits in table 1 during more than 1 percent of the hours in the 12-month period ending with any month or by more than 3° F.

Table 1

January	40° F	April	65° F	July	84° F	October	73° F
February	40° F	May	75° F	August	84° F	November	58° F
March	54° F	June	84° F	September	82° F	December	48° F

Table 2

January	40° F	April	60° F	July	83° F	October	68° F
February	40° F	May	72° F	August	83° F	November	50° F
March	48° F	June	78° F	September	78° F	December	40° F

(15) Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, of undefined toxicity to fish or other biota shall be resolved in accordance with the latest methods recommended by the U.S. Environmental Protection Agency which shall be used as official guidelines in all aspects where the recommendations may be applicable. Toxic substances shall not exceed 1/10 of the 96-hour median tolerance limit (TLM) as a water quality standard except that other more stringent application factors shall be used when justified on the basis of available evidence.

(16) Unauthorized concentrations of substances are not permitted that alone or in combination with other materials present are toxic to fish or other aquatic life. The determination of the toxicity of a substance shall be based upon the available scientific data base. References to be used in determining the toxicity of a substance shall include, but not be limited to:

Table 2 (cont) - Federal Water Quality Criteria and State Water Quality Standards for the Upper Mississippi River from St. Anthony Falls, Minnesota, to Guttenberg, Iowa

1. "Quality Criteria for Water." EPA-440/9-76-003. United States Environmental Protection Agency, Washington, D.C., 1976.
2. "Water Quality Criteria 1972." EPA-R3-73-003. National Academy of Sciences, National Academy of Engineering. United States Government Printing Office, Washington, D.C. 1974.
3. Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, of undefined toxicity to fish and other biota shall be resolved in accordance with the methods specified in "Water Quality Criteria 1972," "Standard Methods for the Examination of Water and Wastewater," 14th Edition, 1975 (American Public Health Association; New York), or other methods approved by the Department of Natural Resources.

(17) All substances toxic or detrimental to aquatic life shall be limited to nontoxic or nondetrimental concentrations in the surface water. In applying this narrative standard, decisions will be based on the rationale contained in "Quality Criteria for Water," published by the U.S. Environmental Protection Agency (1977).

Unless otherwise stated, criteria in this table are based on a substance's total concentration, because an ecosystem can produce chemical, physical, and biological changes that may be detrimental to organisms living in or using the water. The criteria are specific whenever data are sufficient to make the evaluation and when these are given as specific values. When a specific aquatic life recommendation for a particular water pollutant cannot be made because of lack of information or conflicting information, a recommendation is made to substitute a designated application factor based upon data obtained from a 96-hour bioassay using a sensitive aquatic organism and the receiving water as a dilutant for the toxicity test (EPA Quality Criteria for Water, July 1976).

Water quality criteria do not have direct regulatory authority. However, they form the basis of the water quality standards developed by the States under section 303 of the Clean Water Act of 1977 (Public Law 95-217), with appropriate modifications to account for local conditions.

WATER QUALITY STANDARDS

Water quality standards consist of designated beneficial uses and the criteria necessary to protect those uses. They are legal entities that serve as the basis for determining National Pollution Discharge Elimination System permit effluent limitations for pollutants not specifically addressed in effluent guidelines or for pollutants without sufficiently stringent guidelines. For the classification of designated beneficial uses, multiple-use requirements are placed on water resources. The criteria used in setting up standards take into account local conditions, including actual and projected uses of the water, natural background levels of particular constituents, the presence or absence of sensitive important species, characteristics of the local biological community, temperature and weather, flow characteristics, and synergistic or antagonistic effects of combinations of pollutants.

Under Public Law 95-217, the States are required to review and update their water quality standards to meet the objective of restoring and maintaining the chemical, physical, and biological integrity of the Nation's waters. The standards must reflect the national goal of eliminating the discharge of pollutants into navigable water by 1985 and the interim goal of obtaining water quality conditions, wherever attainable, which will provide for the protection and propagation of fish, shellfish, and wildlife, as well as provide for recreational use in and on the water by 1 July 1983. With these standards, the States are required to maintain water quality, regulate discharges, and develop management plans so that these national goals can be reached. All revisions of water quality standards and management plans have to be reviewed and accepted by the EPA. Also, the EPA has the power to develop water quality standards and other management plans if the States fail to submit adequate standards and/or plans of their own. Water quality standards for Minnesota, Wisconsin, and Iowa for the Upper Mississippi River from the St. Anthony Falls upper lock and dam to Guttenberg, Iowa, were shown in table 2.

DESIGNATED BENEFICIAL USES

The uses that have been designated by the States of Minnesota, Wisconsin, and Iowa are discussed below only for the portion of the river from the upper lock and dam at St. Anthony Falls to lock and dam 10 at Guttenberg, Iowa.

Within these boundaries, none of the three States has designated the Mississippi River as a source for domestic consumption. However, it should be noted that areas on the Mississippi River above and below these boundaries have been designated for domestic consumption. Figure 1 shows the classifications developed by the States and the areas on the Mississippi River to which they apply.

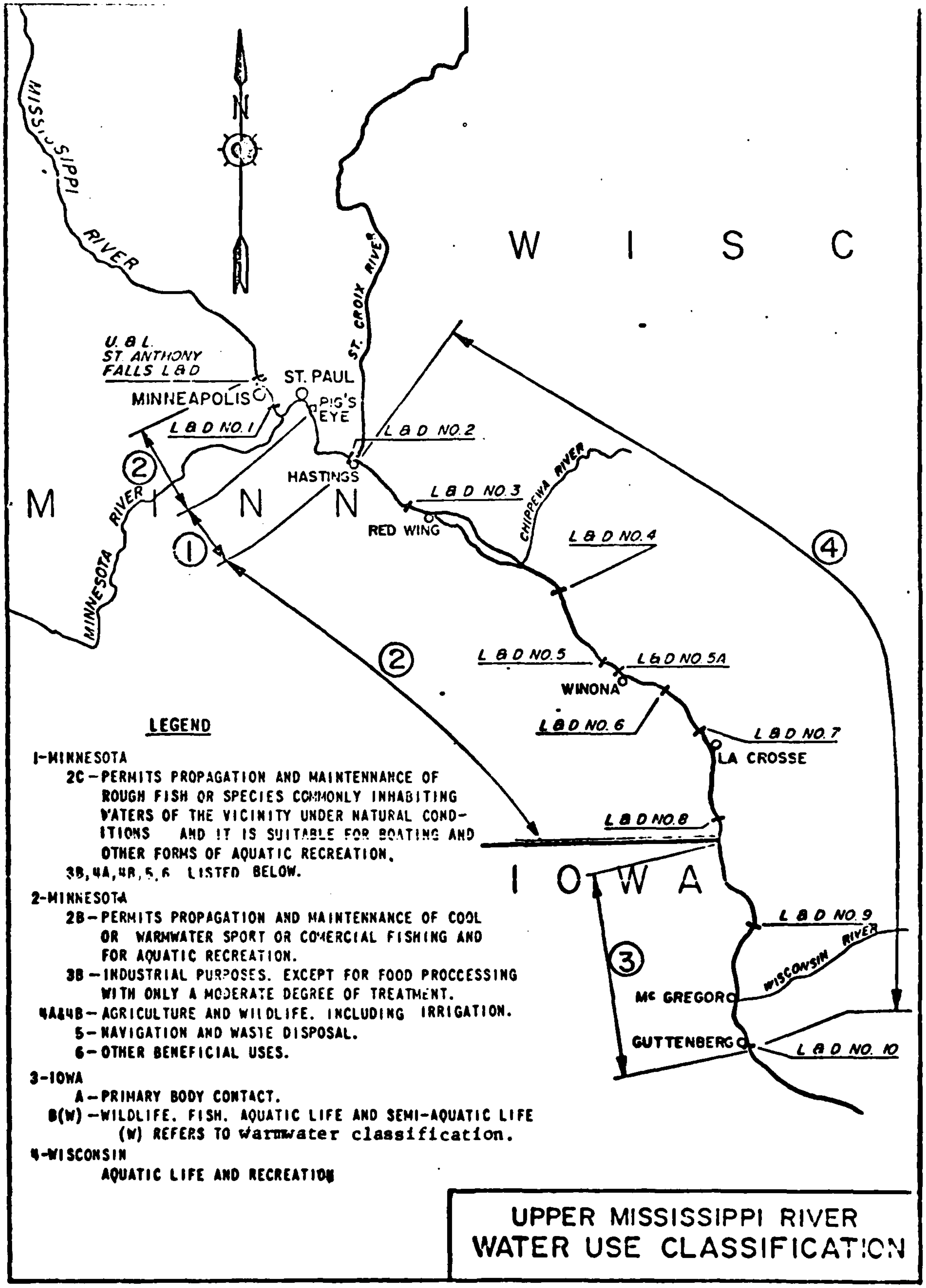

UPPER MISSISSIPPI RIVER
WATER USE CLASSIFICATION
MISSISSIPPI RIVER
ST. CROIX RIVER
W I S C
U. & L.
ST. ANTHONY
FALLS L&D
MINNEAPOLIS
ST. PAUL
PIG'S EYE
L & D NO. 1
L & D NO. 2
HASTINGS
M I N N
MINNESOTA RIVER
L & D NO. 3
RED WING
CHIPPEWA RIVER
L & D NO. 4
L & D NO. 5
L & D NO. 5A
WINONA
L & D NO. 6
L & D NO. 7
LA CROSSE
L & D NO. 8
I O W A
L & D NO. 9
WISCONSIN RIVER
Mc GREGOR
GUTTENBERG
L & D NO. 10
LEGEND
1-MINNESOTA
2C – PERMITS PROPAGATION AND MAINTENANCE OF ROUGH FISH OR SPECIES COMMONLY INHABITING WATERS OF THE VICINITY UNDER NATURAL CONDITIONS AND IT IS SUITABLE FOR BOATING AND OTHER FORMS OF AQUATIC RECREATION.
3B, 4A, 4B, 5, 6 LISTED BELOW.
2-MINNESOTA
2B – PERMITS PROPAGATION AND MAINTENANCE OF COOL OR WARMWATER SPORT OR COMMERCIAL FISHING AND FOR AQUATIC RECREATION.
3B – INDUSTRIAL PURPOSES. EXCEPT FOR FOOD PROCCESSING WITH ONLY A MODERATE DEGREE OF TREATMENT.
4A&4B – AGRICULTURE AND WILDLIFE. INCLUDING IRRIGATION.
5 – NAVIGATION AND WASTE DISPOSAL.
6 – OTHER BENEFICIAL USES.
3-IOWA
A – PRIMARY BODY CONTACT.
B(W) – WILDLIFE. FISH. AQUATIC LIFE AND SEMI-AQUATIC LIFE
(W) REFERS TO Warmwater classification.
4-WISCONSIN
AQUATIC LIFE AND RECREATION

Figure 1

Minnesota

The Mississippi River from lock and dam 2 at Hastings to the Iowa border and from the St. Anthony Falls upper lock and dam to the outfall of the Metropolitan Wastewater Treatment Plant (St. Paul) is classified as 2B and 3B by the State of Minnesota. The quality of class 2B waters permits the propagation and maintenance of cool or warmwater sport or commercial fishing and is suitable for aquatic recreation of all kinds, including bathing. Class 3B waters are designated for general industrial purposes, except for food processing, with only a moderate degree of treatment. Class 3B waters "shall be generally comparable to class(1)D interstate waters used for domestic consumption" and are expected to meet public health standards for drinking water after treatment consisting of coagulation, sedimentation, filtration, storage, chlorination, and additional stages of treatment.

The Mississippi River from the outfall of the Metropolitan Wastewater Treatment Plant to lock and dam 2 at Hastings is classified as 2C and 3B. The quality of class 2C waters permits the propagation and maintenance of rough fish or species commonly inhabiting waters of the vicinity under natural conditions and is suitable for boating and other forms of aquatic recreation.

In addition, where the Mississippi River can be used for agriculture and wildlife, including irrigation, navigation, waste disposal, and other beneficial uses, separate classifications and attendant standards apply (classes 2C, 3C, 4A, 4B, 5, and 6). The most stringent standards of multiple classifications apply.

Wisconsin

In Wisconsin, the Mississippi River is designated for commercial and recreational fishing, industrial and cooling water supply, boating, hunting, commercial shipping, and waste assimilation. Water quality of the river must meet the standards and requirements set forth for recreational use and fish and aquatic life, as indicated in the Wisconsin Administrative Code.

Iowa

The Mississippi River has been designated as class A and B(W) in the State of Iowa. Class A waters "are to be protected for primary contact water use," with attendant standards. Class B waters are protected for wildlife, fish, aquatic and semiaquatic life, and secondary contact uses; B(W) refers to a warmwater subclassification for fish and aquatic life uses.

FUTURE WATER QUALITY STANDARDS AND CRITERIA

The Federal water quality criteria are being updated by the EPA. An addition to the Redbook (EPA Quality Criteria for Water, 1976) should be published in 1979.

Minnesota's water quality standards are being updated by the MPCA and are expected to receive a public hearing in the fall of 1978. The proposed standards are for the most part identical to the criteria outlined in the Redbook. The classification of use is also being updated. "The proposed classification system attempts to group waters by management classes that will reflect the primary resource values of the waters. The water resources are to be assessed individually with respect to numerous water uses (both existing and potential), water quality, environmental factors, related land uses and other special characteristics or factors" (Anderl, MPCA, personal communication, 1978).

Iowa's water quality standards were updated in 1977 and are to remain in effect until the next required updating in 1980.

Wisconsin is updating its standards, but has not yet released any proposed water quality standards.

EFFLUENT REGULATIONS

Under Section 402 of the Water Pollution Control Act of 1972 (Public Law 92-500), a National Pollution Discharge Elimination System (NPDES) was established. The NPDES authorized the States to develop a permit program for point sources discharging into navigable waters. The permit system was established to insure compliance of point source discharges with Federal and State regulations and standards. Under these permit programs, effluent limitations to be met by 1 July 1977 were required to reflect the application of the "best practicable control technology currently available," and by 1 July 1983, the "best available control technology economically available" (Section 301, Water Pollution Control Act, 1972, Public Law 92-500). The "best practicable control technology currently available" requirement includes secondary treatment of all point source discharges. Under Sections 13 and 31 of the Clean Water Act, 1977. (Public Law 95-217), the 1 July 1977 treatment requirements were amended. The amendments provide for time extensions, on a case by case basis, up to 1 July 1982, or if innovative technology is to be used, up to 1 July 1983. In addition, the amendments provide that industrial point source dischargers applying innovative technology could receive an extension of the deadline for compliance with "best available technology" requirements for a maximum of 2 years beyond the 1 July 1983 deadline.

Federal guidelines governing all point source dischargers have been developed by the EPA in the Code of Federal Regulations. These require secondary treatment or the equivalent for all point source discharges (40 Code of Federal Regulations, Part 133, Amended, 26 July 1976). The secondary treatment should provide sufficient removal to meet the general standards discussed below. BOD_5 and suspended solids should have the arithmetic mean of values over

30 consecutive days not in excess of 30 milligrams per liter. The arithmetic mean of values for 7 consecutive days should not exceed 45 milligrams per liter. There must also be an 85-percent (arithmetic mean) removal of BOD and suspended solids from influent to effluent over 30 consecutive days. The pH value in the effluent should be maintained within the limits of 6.0 to 9.0. State effluent standards follow these guidelines very closely. Other pollutants are addressed specifically in the States' permit systems if they are applicable.

Federal regulations governing specific types of dischargers are covered in 40 Code of Federal Regulations 400-460. It should be noted, however, that most of these regulations are undergoing constant revision.

When the point dischargers meet the final effluent standards addressed under the NPDES, the quality of the Nation's waters should improve. However, nonpoint sources such as urban runoff, rural runoff, and natural background levels will continue to add to the pollution problem.

SEDIMENT STANDARDS AND CRITERIA

Interim guidelines for sediment quality in the Great Lakes have been developed by the Region V office of the EPA. However, at present, standards or working guidelines for sediments have not been developed for the Upper Mississippi River.

The Great Lakes sediment classification has been criticized by the Corps and others. This classification is based on bulk chemical analysis of the sediments (extraction with a strong acid), which does not totally represent the toxic potential of pollutants during resuspension of the sediments from dredging and disposal activities.

A classification based on elutriate studies (water extraction) or a combination of the two methods may be more useful in establishing a sediment classification for the Mississippi River (Pequegnat et al., DMRP, January 1978).

As outlined in their proposals to monitor 1978 dredging activities on the Mississippi River, the Corps plans to undertake a sediment study which will help in this classification. This study, coupled with the 1974 and 1975 Corps study of sediment chemistry on the Upper Mississippi River and future studies, should provide a basis for setting up guidelines on sediment quality from which policy decisions relating to dredging and other activities can be made.

SEDIMENT CONDITIONS

Local sediment quality is dependent on many things, such as the amount of pollutants entering the water system from point and nonpoint sources, the distance downstream from those sources, sedimentation rate and associated particle size distribution, and natural background levels.

Sediment pollution has a direct impact on lower aquatic life forms living in or near the sediments where the pollutants are concentrated. It also has an indirect effect, via the food web, on higher organisms, especially those organisms that exhibit bioaccumulation and biomagnification of various pollutants. Resuspension of pollutants concentrated in sediments can result from natural events, such as leaching and erosion, or from man's activities, such as dredging and shipping. It should be noted that all the pollutants in a given sediment may not be in a chemical form available to organisms, even during resuspension (Pequegnat et al., DMRP, January 1978). Furthermore, detection of high or low concentrations of a given component within the sediments does not necessarily dictate that it will be found in corresponding high or low concentrations in the water when the sediments are resuspended (GREAT I WQWG, Grey Cloud Island, 1976).

Within the last 20 years, the sedimentation rates observed in all studies of the pools and backwater lakes have exceeded 2 cm/year; and in the last decade, rates as great as 5cm/year were measured. Fine sediments accumulate in the slack-water pools and backwater areas, but are seldom deposited in the navigational channel because of navigational disturbances, currents, and other natural processes. Sands, however, may be deposited throughout the pool system (GREAT I Sediment and Erosion Control Work Group, June 1976). Bottom sediment particle size distribution is directly reflected in sedimentation rates.

Generally, bottom sediment particle size for the navigational channel of the Upper Mississippi River ranges from coarse to fine sands (see table 3). However, certain notable exceptions occur. In Lake Pepin and the lower portion of Spring Lake, the sediments consist of silty clay with very little sand, because the reduced flow through these areas allows the finer material to settle out. Fine sediments also occur below the outfall of the Metropolitan Wastewater Treatment Plant at Pig's Eye (GREAT I WQWG sediment data, 1976). In backwater areas a similar situation exists and sediments consist mainly of silt and clay with occasional sandy areas (GREAT I, Sediment and Erosion Control Work Group, June 1976, and Fremling et al., July 1976).

Table 3 - Particle size analysis of Upper Mississippi River bottom sediments collected by GREAT I WQWG in 1974
(Laboratory analysis conducted by Geotechnical Engineering Corporation

River Mile	Dry weight percent composition: Gravel (≥6mm.)	Sand (6mm.-.075mm.)	Silt and Clay (<.075mm.)	Classification *
855.0	0	100	0	medium (fine) sand
853.5	46	54	0	gravelly sand
851.63	0	100	0	fine (medium) sand
850.11	1	99	0	fine (medium) sand
848.24	13	87	0	gravelly sand
844.93	90	10	0	sandy gravel
843.36	28	72	0	gravelly sand
841.12	66	34	0	sandy gravel
840.32	2	98	0	medium (coarse) sand
839.04	8	89	3	silty sand and gravel
837.2	0	100	0	fine (medium) sand
835.07	—	---	88	sandy silt and clay
833.03	—	---	67	sandy silt and clay
831.0	15	85	0	gravelly sand
827.84	0	100	0	medium (fine) sand
826.0	2	98	0	medium (fine) sand
823.39	0	100	0	fine sand
821.0	1	99	0	medium (fine) sand
819.0	1	99	0	medium (fine) sand
817.0	—	---	84	sandy silt and clay
815.39	—	---	81	sandy silt and clay
815.0	0	100	0	fine (medium) sand
813.18	22	78	0	gravelly sand
811.14	1	99	0	medium sand
809.0	0	100	0	medium (fine) sand
807.0	0	100	0	medium (fine) sand
805.0	0	100	0	medium (fine) sand
802.69	1	99	0	medium sand
801.0	1	99	0	fine (medium) sand
799.12	0	100	0	fine (medium) sand
797.0	3	97	0	medium (coarse) sand
794.29	0	100	0	medium (fine) sand
792.54	0	100	0	fine (medium) sand
790.50	1	99	0	fine (medium) sand
787.71	0	93	7	silty or clay sand
785.0	0	100	0	fine (medium) sand
772.79	—	—	99	sandy silt and clay
764.88	—	—	94	sandy silt and clay
759.08	0	100	0	medium (coarse) sand
757.49	4	96	0	medium (coarse) sand
754.0	0	100	0	fine (medium) sand
752.0	0	100	0	medium (fine) sand
750.4	3	97	0	medium (fine) sand
747.72	1	99	0	medium (fine) sand
745.0	1	99	0	fine (medium) sand
743.28	0	100	0	fine (medium) sand
741.0	0	100	0	fine (medium) sand
739.0	4	90	6	silty sand and gravel
737.0	2	98	0	medium (coarse) sand
734.48	3	97	0	medium (coarse) sand
732.60	0	100	0	medium (fine) sand
730.32	1	99	0	medium (fine) sand
728.12	5	95	0	gravelly sand
726.4	0	100	0	medium (fine) sand
724.0	12	88	0	gravelly sand
722.0	1	99	0	medium (fine) sand
720.66	1	99	0	medium (coarse) sand
718.0	0	100	0	medium (fine) sand
716.36	0	100	0	medium (fine) sand

Table 3 (cont) - Particle size analysis of Upper Mississippi River bottom sediments collected by GREAT I WQWG in 1974
(Laboratory analysis conducted by Geotechnical Engineering Corporation)

River Mile	Dry weight percent composition: Gravel (>6 mm.)	Sand (6 mm.-.075 mm.)	Silt and Clay (<.075 mm.)	Classification*
714.0	0	100	0	medium (fine) sand
711.64	1	99	0	medium (fine) sand
709.0	0	100	0	medium (fine) sand
706.32	1	99	0	medium (fine) sand
704.92	0	100	0	medium (fine) sand
703.08	0	100	0	medium (fine) sand
701.0	0	100	0	medium (fine) sand
699.0	0	100	0	medium (fine) sand
697.0	0	100	0	medium (fine) sand
694.72	0	100	0	medium (fine) sand
692.0	2	98	0	medium (fine) sand
690.0	1	99	0	fine (medium) sand
688.08	0	100	0	fine (medium) sand
686.0	7	93	0	fine (medium) sand
684.0	0	97	3	silty sand
682.0	1	99	0	medium (fine) sand
680.0	0	96	4	silty sand
678.0	0	100	0	medium (fine) sand
676.0	0	100	0	medium (fine) sand
674.0	0	100	0	medium (fine) sand
671.44	1	99	0	medium (fine) sand
669.36	0	100	0	medium (fine) sand
667.44	0	100	0	fine (medium) sand
664.44	1	99	0	fine (medium) sand
662.44	0	100	0	medium (fine) sand
660.58	0	100	0	medium (fine) sand
658.60	0	100	0	medium (fine) sand
656.0	0	99	1	fine (medium) sand
654.0	0	91	9	silty sand
651.0	0	97	3	silty sand
648.14	0	95	5	silty sand
646.24	0	100	0	fine (medium) sand
643.24	0	100	0	fine (medium) sand
637.0	38	62	0	gravelly sand
633.2	0	100	0	medium (fine) sand
633.0	5	90	5	silty & gravelly sand
631.0	0	77	23	silty sand
627.64	1	99	0	medium (fine) sand
624.0	0	100	0	medium (fine) sand
621.0	0	100	0	medium (fine) sand
618.56	0	100	0	fine (medium) sand

* The first key word indicates the primary contributor; the key word in parenthesis, the second major contributor to total particle size.

In various studies, sediments for the Upper Mississippi River were analyzed for PCB's. Lake Pepin and Spring Lake showed the highest concentrations: as high as 4,400 ppb (parts per billion) in Lake Pepin (GREAT I SECWG, 1977) and 550 ppb in Spring Lake (PCB Interagency Task Report, 1976). In addition to the PCB studies, bulk chemical analysis was conducted on sediments from the Upper Mississippi River navigational channel by the Corps. Tables 4 and 5 show the data collected for 1974 and 1975 (GREAT I WQWG, Grey Cloud Island, 1976).

Table 4 - Bulk chemical analysis of Upper Mississippi River bottom sediment samples collected November 74
(Laboratory analysis performed by SERCO, Inc., for GREAT I WQWG)
(Samples collected by Ponar Bottom Sampler)
(All concentrations are reported on a dry weight basis)

Sample number	River mile	Arsenic µg/g	Cadmium µg/g	Total chromium µg/g	Copper µg/g	Lead µg/g	Mercury µg/g	Nickel µg/g	Zinc µg/g	Oil mg/g	Total phosphorus µg/g	COD mg/kg	Kjeldahl mg/kg	% Volatile solids	% Total solids
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	(657.49)	<0.9	1	10	5	<10	0.7	8	33	190	175	2247	150	0.4	93.1
4	(651.63)	<0.6	<1	8	5	<10	0.3	5	16	247	135	4700	209	0.5	92.4
5	(650.11)	<1.0	2	10	10	19	1.1	7	29	314	201	5032	548	0.7	77.4
6	(649.24)	<0.8	1	8	11	<11	1.1	6	24	396	170	5243	135	0.5	78.1
6	(648.24)	<0.9	<1	9	12	<12	0.6	3	23	374	400	8243	145	0.5	75.4
9	(643.50)	<0.8	<1	15	10	<10	4.6	12	19	256	192	1401	185	0.7	84.1
11	(640.32)	<0.8	<1	12	3	12	0.6	12	18	773	216	<457	447	0.5	79.2
13	(637.20)	<0.8	0.9	9	2	<9	1.1	5	12	318	210	1874	134	0.6	84.2
14	(635.07)	1.8	6	43	33	95	0.8	35	143	1269	1130	101,355	422	6.2	43.5
15	(633.05)	1.2	15	115	36	73	0.8	42	170	884	1697	75,146	2727	8.3	34.5
17	(827.61)	<0.8	<1	12	5	<10	0.7	10	19	76	177	950	236	0.4	79.3
17	(827.84)	<0.9	<1	10	2	<10	0.4	7	20	64	250	511	138	0.4	77.8
19	(823.5[illegible])	<1.0	1	29	5	<11	0.8	19	14	285	143	4077	97	0.4	75.[illegible]
20	(821.00)	<0.8	1	8	2	<10	1.8	5	19	204	217	2872	75	0.5	83.0
23	(815.39)	1.0	3	39	10	<13	0.7	29	44	163	930	14,184	293	28.7	54.9
30	(802.63)	<0.9	<1	6	3	< 9	0.5	3	76	<6	247	431	235	0.5	84.3
35	(792.54)	<0.7	<1	17	10	< 6	0.4	77	15	59	164	2553	61	0.7	77.4
38	(785.00)	<1.0	<1	29	2	< 9	<0.1	17	13	140	205	1712	59	0.6	83.[illegible]
38	(785.05)	<1.0	<1	30	5	< 9	<0.1	18	12	147	225	2303	145	0.7	83.[illegible]
39	(772.7[illegible])	4.0	9	116	58	47	5.4	35	185	2825	1769	113,005	4121	14.5	19.[illegible]
41	(763.00)	<0.9	<1	8	10	< 7	0.3	8	19	85	232	772	49	0.6	90.[illegible]
41	(763.0[illegible])	<1.0	<1	5	7	< 7	0.2	5	13	60	227	960	44	0.7	81.9
42	(759.[illegible])	<0.9	1	7	7	< 7	1.4	7	17	101	235	<491	117	0.4	82.6
42	(759.0[illegible])	1.0	1	7	7	< 7	0.6	7	17	126	185	<453	42	0.6	82.[illegible]
43	(757.4[illegible])	0.9	1	6	6	<11	0.4	6	16	801	117	<515	66	0.5	94.[illegible]
44	(756.3[illegible])	<0.8	<1	7	10	< 7	0.4	5	15	756	229	<4[illegible]	13	0.7	95.[illegible]
45	(754.0[illegible])	<0.7	<1	23	8	28	0.4	17	17	624	166	5507	273	0.7	54.[illegible]
48	(747.72)	<0.6	1	7	7	<10	0.9	5	30	699	177	1096	52	0.4	94.[illegible]
49	(745.0[illegible])	10.9	<1	5	10	<10	0.3	5	13	<6	194	1273	52	0.3	91.[illegible]
49	(745.0[illegible])	0.9	<1	5	8	<10	0.2	5	13	<6	119	[illegible]	134	0.4	82.[illegible]
50	(743.22)	<0.6	<0.7	33	5	< 7	0.4	26	13	530	142	13[illegible]	107	0.4	83.[illegible]
54	(734.0[illegible])	0.8	<1	7	5	< 9	0.2	10	23	398	140	414	48	0.4	55.[illegible]
55	(732.0[illegible])	0.7	<0.8	8	6	< 8	0.3	6	35	385	152	<401	125	0.3	66.[illegible]
56	(730.32)	<0.8	<0.8	6	6	< 8	0.2	6	16	64	142	<456	90	0.5	95.3
58	(726.4[illegible])	<1.0	0.7	5	4	< 7	0.3	4	13	58	155	404	276	0.4	65.[illegible]
61	(720.4[illegible])	<0.7	<1	7	5	< 9	0.2	5	17	452	167	424	160	0.9	85.[illegible]
65	(711.6[illegible])	<0.9	<1	7	5	< 9	0.2	9	16	439	209	<401	11	0.4	84.[illegible]
65	(709.0[illegible])	<0.8	1	8	5	10	0.4	5	15	409	205	416	123	0.4	83.[illegible]
66	(709.[illegible])	<0.9	<0.9	7	4	< 9	0.3	7	16	371	237	1417	145	0.4	[illegible]
67	(706.3[illegible])	<0.9	<0.9	7	5	9	0.1	5	14	34	200	444	112	0.4	[illegible]
69	(701.9[illegible])	<0.9	<0.6	6	6	< 6	0.4	6	19	149	375	47[illegible]	103	0.5	55.[illegible]
73	(694.[illegible])	<0.7	<0.9	7	5	< 9	0.4	7	14	673	191	30[illegible]	187	0.4	[illegible]
7[illegible]	(69[illegible])	<0.7	<0.6	6	6	< 8	0.2	8	15	535	194	33[illegible]	123	0.4	[illegible]
74	(692.0[illegible])	<0.7	0.9	7	5	< 9	<0.1	7	14	539	190	[illegible]	147	0.5	[illegible]
75	(6[illegible])	<0.8	0.9	106	7	< 9	0.5	36	16	526	101	13[illegible]	[illegible]	0.3	[illegible]
[illegible]	(671.44)	<0.9	0.9	14	4	< 9	0.1	7	15	23	[illegible]	[illegible]	13[illegible]	0.5	[illegible]
[illegible]	(66[illegible].4[illegible])	<0.7	0.9	24	4	9	0.5	4	12	326	[illegible]	[illegible]	14[illegible]	0.3	[illegible]
[illegible]	(651.[illegible])	<0.8	0.9	11	4	< 9	0.2	4	13	11	[illegible]	[illegible]	[illegible]	0.5	65.[illegible]
[illegible]	(64[illegible])	<0.8	<0.9	4	2	< 9	0.6	4	9	340	[illegible]	[illegible]	[illegible]	0.3	64.4
[illegible]	(633.[illegible])	0.9	1	94	5	11	0.2	28	25	315	[illegible]	12,[illegible]	[illegible]	1.7	[illegible]
[illegible]	(621.[illegible])	<0.9	<0.9	9	2	< 9	<0.1	2	11	327	[illegible]	[illegible]	[illegible]	0.4	[illegible]
		[illegible]	[illegible]	9	[illegible]	< 9	<0.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.3	[illegible]

Table 4 (cont) - Bulk chemical analysis of Upper Mississippi River bottom sediment samples collected November 1974 (Laboratory analysis performed by SERCO, Inc., for GREAT I WQWG) (Samples collected by Ponar Bottom Sampler) (All concentrations are reported on a dry weight basis)

Sample number	River mile	Aldrin µg/g	Chlordane µg/g	Methoxychlor µg/g	Toxaphene µg/g	Dieldrin µg/g	Endrin µg/g	Thiodan µg/g	DDE µg/g	TDE µg/g	DDT µg/g	Lindane µg/g	BHC µg/g	Heptachlor µg/g	Heptachlor epoxide µg/g
1	(857.48)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1	(857.48)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4	(851.63)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
5	(850.11)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
6	(848.24)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
6	(849.24)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
9	(852.56)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
11	(840.32)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
13	(837.20)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
14	(835.97)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
15	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
17	(827.84)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
17	(827.84)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
19	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
20	(821.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
23	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
29	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
33	(792.34)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
38	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
39	(785.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
39	(772.79)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
41	(763.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
41	(763.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
42	(759.08)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
42	(759.06)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
43	(757.49)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
44	(756.32)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
45	(754.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
48	(747.72)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
47	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
47	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
50	(743.22)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
54	(734.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
55	(732.60)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
56	(730.32)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
59	(726.40)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
[illegible]	(720.46)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
65	(711.64)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
66	(709.00)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
66	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
67	(706.32)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
68	(704.92)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
73	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
74	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
74	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
76	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
[illegible]	(671.44)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
[illegible]	(664.44)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
[illegible]	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
[illegible]	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
[illegible]	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
[illegible]	(637.54)	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
[illegible]	[illegible]	<0.01	<0.01	<0.05	<0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 5 - Bulk chemical analysis of Upper Mississippi River bottom sediment samples collected April 1975 (Laboratory analysis performed by Twin City Testing and Engineering Lab., Inc., for U.S. Army Corps of Engineers, St. Paul, Minnesota)

(All concentrations are reported on a dry weight basis)

Sample (river mile)	Arsenic µg/g	Cadmium µg/g	Total Chromium µg/g	Copper µg/g	Lead µg/g	Mercury µg/g	Zinc µg/g	Oil & Grease µg/g	Total Phosphorus µg/g	Chemical Oxygen Demand mg/Kg	Total Kjeldahl Nitrogen mg/Kg	Ammonia Nitrogen mg/Kg	% Volatile Solids (dry wt.)	% Total Solids (dry wt.)
1 (745.2-left)	0.40	< 0.1	5.9	6.6	<0.1	0.035	24.5	[illegible]	0.2[illegible]	1226	[illegible].61	0.01	1.4	[illegible]
2 (745.2-center)	0.41	< 0.1	4.9	6.0	<0.1	0.035	16.2	15	0.21	1103	2.35	0.11	1.5	99.4
2-1 (745.2-center)	0.45	< 0.1	5.6	5.4	<0.1	0.029	16.4	29	0.24	1274	3.11	0.12	1.5	99.6
3 (745.2-right)	0.38	< 0.1	5.5	5.7	<0.1	0.031	19	973	0.31	2810	9.01	0.05	1.6	99.3
4 (747.7-right)	0.57	< 0.1	7.7	19.8	<0.1	0.059	21.1	1471	0.45	4340	6.06	0.40	1.3	94.3
5 (848)	2.2	4.3	37.5	39.7	118	0.40	159	3160	1.10	91600	59.2	1.98	11.0	83.2
6 (848)	1.6	< 0.1	9.6	24.0	<0.1	0.09	40.9	1147	0.90	26334	19.4	0.50	2.9	92.1
7 (837.5-right)	1.50	1.0	13.3	10.4	36.5	0.051	42.7	1712	0.75	16600	14.3	0.59	3.0	97.8
7-1 (837.5-right)	1.56	0.9	10.9	9.7	28.4	0.058	41.3	1625	0.68	15755	13.8	0.55	2.7	95.5
8 (840.4-center)	0.36	< 0.1	8.6	3.5	<0.1	0.079	16.1	47	0.24	1850	3.25	0.10	1.4	99.7
9 (851.6-left)	0.46	< 0.1	8.0	4.3	<0.1	0.14	24.0	245	0.29	3700	7.56	0.75	1.7	99.3
0 (855.1-center)	0.55	< 0.1	7.4	6.3	<0.1	0.12	19.9	399	0.20	6860	8.26	0.32	1.7	96.0
11 (12.0-center)*	0.83	< 0.1	7.0	2.8	<0.1	0.13	14.9	218	0.54	1950	3.65	0.10	1.6	99.5
12 (822.9-left)	0.94	2.7	31.7	13.9	10.0	0.07	55.3	483	2.60	15600	15.1	0.51	3.0	99.2
3 (822.9-center)	0.62	1.3	16.5	9.0	9.7	0.048	30.7	374	1.11	7050	6.35	0.10	2.0	99.4
14 (822.9-right)	0.30	< 0.1	9.2	5.0	<0.1	0.064	21.3	284	0.80	2396	5.1	0.14	1.3	97.5
4-1 (822.9-right)	0.23	< 0.1	9.2	4.9	<0.1	0.043	20.5	204	0.88	1848	3.0	0.10	1.7	97.9
5 (827.7-right)	0.45	< 0.1	16.5	7.9	<0.1	0.027	[illegible]	133	1.9[illegible]	4850	5.74	0.20	1.8	[illegible]

* Minnesota River

In assessing these data, it should be pointed out that concentrations of pollutants may vary considerably at any given site. Bottom material types may be vertically or horizontally stratified at any given site within the navigational channel. Because of this stratification, it is difficult to characterize an area from one sample and one sampling method. In addition, concentrations of given components for a particular area may be transient and seasonal (GREAT I WQWG, Grey Cloud Island Study, 1976).

However, these data and other studies point to three major problem areas in regard to sediment quality: the area immediately below the outfall of the Metropolitan Wastewater Treatment Plant, Spring Lake, and Lake Pepin. PCB's, pesticides, metals, and nutrients tend to be associated more with fine sediments than with coarse sediments. This association seems to correspond well with the results of particle size studies that identified these three areas as consisting of fine sediments (clays and silts).

Most of the metals analyzed in these three areas exhibited comparatively high concentrations. For example, mercury (which is always an environmental concern) was detected in Lake Pepin at 5.4 ppm (parts per million) in one study (table 4) and at 4.5 ppm in another (GREAT I WQWG, Lake Pepin Study, 1978).

Oil detected near the outfall of the Metropolitan Wastewater Treatment Plant at Pig's Eye and in Lake Pepin was above the 1,000 ug/kg (hexane extractable substances) proposed MPCA sediment standard to protect aquatic life. For the most part, pesticides were present in very low concentrations, usually below the detection limits, in Upper Mississippi River sediments. However, in one study, DDD, DDT, and chlordane were found in Lake Pepin at concentrations greater than 2 ppb (GREAT I WQWG, Lake Pepin Study, 1978), and, in another study, DDD and DDE were found at levels greater than 8 and 4 ppb, respectively (Corps of Engineers, unpublished data, 1978).

The sediments in these three areas also contain a high degree of organic material, as shown by the percentage of volatile solids in table 4: as high as 28 percent in the Spring Lake area, 14 percent in Lake Pepin, and 8 percent in the vicinity of Pig's Eye. In addition, nutrient levels, phosphorus, and nitrogen are very high in these three areas. These materials reach levels similar to those others have reported for eutrophic lakes (Fremling et al., 1976).

Bacterial contamination of the sediments, although not well documented, may be a problem on the Mississippi River (especially near major sewage outfalls). High values of total and fecal coliform in the sediments were found below the Twin Cities metropolitan area (GREAT I WQWG, Grey Cloud Island Study, 1976). Water quality may be locally degraded when these sediments, highly contaminated with bacteria, are resuspended during dredging (GREAT I WQWG, Grey Cloud Island, 1976) or as a consequence of other navigational activities.

For the three major problem areas on the Upper Mississippi River, many of the pollutants in tables 4 and 5 exceeded the classification for heavily polluted areas in the Great Lakes. The areas outside of these three problem areas never had pollutant levels (with the exception of copper and chromium) greater than the nonpolluted classification for the Great Lakes. Because of the complicated nature of determining sediment quality, the difference in classification of use, and the great difference in the ecology of the Great Lakes and the Mississippi River, one cannot extend the application of these criteria too closely to the Mississippi River.

WATER QUALITY CONDITIONS

A variety of substances which can affect water quality are commonly introduced into river systems. Sources of these substances include: domestic or municipal wastes; runoff from agricultural land, storm sewers, and mining areas; and industrial discharges. In recent years, water quality conditions in the Upper Mississippi River basin have been upgraded by the implementation of the Federal Water Pollution Control Act of 1972 which stipulates that all waters of the United States must be "fishable, swimmable" by 1983. In addition, States have adopted stringent water quality standards.

Because of the large population and physical size of the Twin Cities metropolitan area, much of the GREAT I river basin continues to experience serious pollution problems, particularly downstream of this area. Problems in other segments of the GREAT I river basin can be attributed mainly to agricultural runoff and domestic waste. In order to provide a picture of water quality conditions within the Upper Mississippi River basin, the navigable portions have been discussed in more detail below. Information has been drawn from several sources (Iowa Department of Environmental Quality, 1975; MPCA, 1977, 1978; WDNR, 1978; USGS, 1977).

Mississippi River

The MPCA (1977) indicates that there are approximately 100 dischargers within the Twin Cities metropolitan segment of the Mississippi River. The dischargers include 5 wastewater treatment plants, 2 agricultural feedlots, 6 water treatment plants, and 26 industries (not including noncontact cooling water discharges). Because of this intensive municipal and industrial use and additional nonpoint source runoff, that portion of the river from the Metropolitan Wastewater Treatment Plant to lock and dam 2 at Hastings has been assigned a lower use classification than other areas of the basin. This portion is not recommended for primary body contact recreation or as a drinking water supply because of heavy pollution loading. Water quality does not improve significantly until the river passes lock and dam 2 and joins the St. Croix River. Proposed MPCA regulations would upgrade this portion of the river to a future fishable, swimmable classification.

Fecal coliforms, which indicate human pollution and the potential presence of pathogens, are exceedingly high in the metropolitan segment. The 200/100-ml (milliliter) standard is frequently violated, especially below the Metropolitan Wastewater Treatment Plant downstream from St. Paul, which adds to the already deteriorated condition of the river. Occasional violations continue between locks and dams 2 and 10, but levels are generally below 100/100 ml.

Dissolved oxygen, which is extremely important for the maintenance and propagation of aquatic life, varies considerably in concentration from the head of navigation down to lock and dam 10. Dissolved oxygen at the point where the Mississippi River enters the metropolitan area does not usually fall below 7.0 ppm. A slight decrease is evident as the river passes through the metropolitan area. Levels occasionally drop as low as 1.0 ppm below the Metropolitan Wastewater Treatment Plant. Levels climb back above 7.0 ppm by lock and dam 2 and generally remain high for the lower portion of the river.

Levels of pH generally remain at the 6.5 to 9.0 criteria recommended by the EPA (1976). Levels drop from a mean of 8.3 above the metropolitan area to 7.8 below St. Paul and the Metropolitan Wastewater Treatment Plant. Mean levels are generally between 8.0 and 8.3 for the remaining stretch of the Mississippi River, but may drop much lower in localized areas.

Turbidity and suspended solids levels are extremely variable throughout the GREAT I reach of the Mississippi River. They are influenced greatly by seasonal discharge rates and are often closely correlated with levels of chemical and biological contaminants which readily attach to sediment particles. Turbidity values often exceed the 25 JTU (Jackson turbidity unit) Minnesota standard during the spring for most of the GREAT I reach of the Mississippi River. During the rest of the year, values are typically between 2 and 20 JTU. Suspended solids concentrations are frequently over 30 mg/1, especially during spring, summer, and fall. Some of the major tributaries of the Mississippi River, particularly the Minnesota and other rivers which drain extensive agricultural areas, frequently exhibit suspended solids concentrations above 30 mg/1.

Nutrient concentrations are affected substantially by the metropolitan area. Ammonia nitrogen concentrations, which are approximately 0.2 to 0.3 mg/l above the metropolitan area, occasionally increase to approximately 1.5 mg/l below the Metropolitan Wastewater Treatment Plant and do not return to original concentrations until after lock and dam 3. Other forms of nitrogen and phosphorus follow much the same pattern. Total phosphorus levels are 0.1 to 0.2 mg/l above the metropolitan area and are more than doubled below the metropolitan area, before falling to 0.2 to 0.3 mg/l in the lower reaches.

Heavy metals often exceed standards in localized areas of the river and are extremely important contaminants in light of their potential for bioaccumulation and synergistic effects. Iron and manganese are present in the greatest concentrations in both sediments and water largely because of their high naturally occurring concentrations. Mercury is often recorded in excess of the 0.05 ug/l EPA (1976) criteria and has been recorded as high as 2.0 ug/l in the metropolitan area and near lock and dam 3.

PCB's and other organics are a problem in some segments of the Mississippi River. PCB levels in fish have exceeded the 5-ppm Food and Drug Administration action level in the metropolitan area and as far downstream as Lake Pepin (Minnesota-Wisconsin PCB Interagency Task Force, 1976).

Minnesota River

The potential for nonpoint source pollution from agricultural runoff is higher than for pollution from other sources in the Minnesota River. Several municipalities and a variety of industries also discharge waste into the 15-mile navigable portion of the lower Minnesota River.

Fecal coliforms occasionally exceed the 200/100 ml State standard but levels are usually much lower during most of the year. Dissolved oxygen levels in the Minnesota River are generally high, ranging from 5 to 14 mg/l during most of the year. However, during the warm summer months, levels may drop below the 5.0 mg/l level suitable for good fish populations. Levels of pH do not represent a problem in the lower Minnesota River, generally ranging from 7.0 to 8.5.

Turbidity and suspended solids standards are frequently exceeded during spring, summer, and fall. Turbidity can climb as high as 90 JTU during spring runoff, and suspended solids have been recorded over 300 mg/l. The Minnesota River contributes substantially higher loads of suspended solids to the Mississippi River where the two rivers join in Minneapolis. Nutrient concentrations fluctuate rather widely during the year. Ammonia levels frequently exceed 1.0 mg/l and phosphorus levels may exceed 0.6 mg/l.

Heavy metals, pesticides, and PCB's usually remain within State standards. Mercury frequently exceeds the 0.05 ug/l EPA (1976) criteria, but does not exceed 0.5 ug/l. Some fish samples taken from the Minnesota River near Mankato contained PCB levels over 10 ppm (Minnesota-Wisconsin PCB Interagency Task Force, 1976).

Specific conductance and hardness are extremely high during much of the year and occasionally exceed State standards.

St. Croix River

The lower St. Croix River is characterized by water of relatively high quality and heavy recreational use. Municipal and industrial sources of pollution are minimal, but agricultural activity can contribute nonpoint source pollutants.

Fecal coliform levels are usually much less than 100/100 ml and rarely exceed the 200/100 ml State standard. Dissolved oxygen levels are between 6 and 14 mg/l for the lower St. Croix River and average approximately 9 mg/l. A good sport fishery exists in this river segment. Mean levels of pH are approximately 8.0 and range between 7.0 and 8.6.

Turbidity and suspended solids are typically low, with turbidity levels below 10 JTU and suspended solids levels below 15 mg/l. Occasionally suspended solids levels have been recorded as high as 60 mg/l.

Nutrient concentrations are moderately low on the lower St. Croix River and present no serious problems.

Heavy metals do not exceed State standards except for rare, isolated instances during the year. Mercury levels frequently exceed the 0.05 ug/l EPA criteria, but remain below 0.5 ug/l (MPCA, 1978). PCB levels in fish from the St. Croix River were well below the FDA action level of 5 ppm (Minnesota-Wisconsin PCB Interagency Task Force, 1976).

SPECIAL PROBLEMS

PCB's

PCB's present a serious threat to human health and the environment. Since their introduction in 1929, PCB's have been used in a variety of commercial and industrial products such as transformers, capacitors, paints, inks, paper, plastics, adhesives, sealants, and hydraulic fluids. However, in 1971 the Monsanto Corporation, the sole domestic manufacturer of PCB's, imposed restrictions on production and essentially eliminated all except closed electrical uses (primarily as a dielectric fluid in transformers and capacitors) (Durfee, 1976). EPA estimates that since 1929 over 700 million pounds have been used in the United States, of

which 400 million pounds have entered the environment (Train, R.E., personal communication, 1976). Because of their widespread past use and because they do not readily degrade, PCB's are widely dispersed throughout the environment.

The criteria recommended by EPA limit PCB levels in all waters to 0.001 ug/l for freshwater life. The FDA recommends an upper limit of 5 parts per million in fish taken for human consumption. Above these levels, it has been shown that PCB's have adverse effects on fish and aquatic life. In addition, they have been found in laboratory tests to cause reproductive failure, gastric disorders, skin lesions, and tumors in mammals.

The direct concern for PCB's in the Upper Mississippi River began when the FDA intercepted a shipment of commercial fish taken from Lake Pepin which exceeded the FDA's "action level" of 5 milligrams per kilogram (ppm) PCB's. An estimated 20,000 pounds of carp fillets were disposed of by the commercial fishermen after they were found to exceed 5 ppm. In addition, a report published by the WDNR indicated high levels of PCB's in fish collected from the Upper Mississippi River (Kleinert, 1975). Because of this report and a growing concern over the effects of PCB's, an interagency task force was created to deal with the problem of PCB's in the Mississippi River and its tributaries. The major objective of this group was to identify the sources of PCB's escaping into the Mississippi River and its tributaries and to determine the extent of the problem so that contamination could be controlled.

In these studies on the Mississippi River, the task force found surface water concentrations, for the most part, below the 0.4 ppb detection limit. The only area which had detectable concentrations was the lower part of Lake Pepin, where the level was 3 ppb. Sediment analysis yielded more information than did the surface water data.

The concentration ranged from 1,000 ppb to below the detection limit of 30 ppb. In another study, PCB's were detected as high as 4,400 ppb in Lake Pepin (GREAT, Sediment and Erosion Control Work Group, 1977, unpublished data). Sediment analysis has shown that Spring Lake in pool 2 and Lake Pepin in pool 4 are PCB sinks or traps. Based on the data collected, the task force found that PCB concentrations in fish flesh seem to vary with the concentrations in the sediment, the species of fish, and the fat content of the fish fillets.

PCB's in individual rough fish and game fish exceeded the 5 mg/kg FDA action level at some of the sampling stations. However, the mean concentration in the fish fillets at any given sampling location did not exceed the action level, with the exception of rough fish collected below lock and dam 1 and in the Spring Lake area on the Upper Mississippi River (PCB Interagency Task Force, 1976).

In another Upper Mississippi River study, Olson and Mauche (1976) found PCB residue in adult mayflies (Hexagenia bilineata) to be as high as 2.9 ug/g. Residue levels were highest in mayflies collected from Lake Pepin.

In monitoring industrial waste, municipal wastewater treatment plants, and sanitary landfills, the PCB Task Force detected PCB's in only a couple samples from each group. It found no single PCB source or group of PCB sources contributing to the Mississippi River. However, high concentrations (3 to 26 ppm) were found in sludge samples from several municipal wastewater treatment plants (PCB Interagency Task Force, 1976). In the limited studies monitoring PCB's in the effluent released from dredging and the subsequent aquatic disposal of dredged material, it was seen that dredging was contributing PCB's to the water column. In the Grey Cloud Island Study, PCB concentration exceeded MPCA standards in the discharge. PCB's were found to be below detection limits 0.01 kilometers downstream from dredging operations, probably because of dilution and the settling effect of fine sediments which adsorb them. However, the Grey Cloud Island study was conducted in

an area of contaminated sediment and does not reflect the availability for resuspension of PCB's from dredged sediment for the entire reach of the Upper Mississippi River (GREAT I WQWG, March 1978). In another study on hydraulic dredging and disposal conducted in pool 7 of the Upper Mississippi River, PCB's were detected in the disposal plume (MPCA, 1 August 1975). In other studies on dredging operations around the country, any release of PCB's is usually at a level below or just slightly above the detection limit (Chen et al., 1976; Fulk et al., 1975; Lee et al., 1975).

Because of the changing detection limits, conflicting data on PCB resuspension, and limited data from current studies, more studies must be conducted to obtain a better understanding of the effects of dredging and disposal on PCB resuspension in the water column.

In a study of barge tow effects on water quality, barge traffic was shown to resuspend sediments into the water column (GREAT I WQWG, Lake Pepin Report, 1978). Resuspension of sediments may be accompanied by resuspension of PCB's. However, in this study PCB concentrations in the water were below the detection limits of the method employed.

PCB contamination of the Mississippi River will linger for many years. Each small source of these persistent chemicals adds to the PCB problem. Control of the many small sources of PCB's can only be accomplished by eliminating the manufacture, sale, purchase, possession, and use of PCB's or products containing PCB's (PCB Interagency Task Force, 1976).

Hazardous Materials

Hazardous material spills have a direct impact on wildlife and aquatic life. They pollute the sediments, an especially important problem because of the potential for resuspension of pollutants during dredging and shipping activities. Public concern over hazardous material and oil spills in water or on land, which drains into water, usually runs very high. In 1970, Congress provided the appropriate

Federal agencies with authority to prevent or mitigate oil spills. The Water Pollution Control Act Amendments of 1972 gave authority for regulation of other hazardous materials; a recently updated list designated 271 hazardous chemicals. Under authority designated by the Federal Water Pollution Control Act, EPA established what it considered a "harmful quantity" of hazardous substances and the rates of penalty for the discharge of these materials (Federal Register, Vol. 43, No. 49, 13 March 1978).

Cleaning up hazardous materials is very difficult. Oil and other substances which do not mix with water are the only substances that have been listed as removable in the Federal Register (10 of 271 on the list). Various techniques have been tried on the Mississippi River, including booming and skimming, control of lock and dam gates, sorbent pads, and pumping. Several methods could be used for those hazardous materials listed as nonremovable: another chemical could be added to the spill area to precipitate out the hazardous material; the spill area could be "stopped off"; or the chemical could be diluted.

Since 1972, over 200 spills (35 of over 1,000 gallons) directly affecting the Upper Mississippi River have been recorded by the EPA. Most spills have consisted of oil and oil derivatives, and most have been under 100 gallons. Some spills have involved soybean oil, raw sewage, asphalt, and very limited amounts of chemicals. Table 6 shows some of the major spills on the Mississippi River from 1975 through June 1978. Over half of the major spills within this period were attributed to barge activity (EPA, unpublished data, 1978).

Major hazardous material spills (greater than 1,000 gallons), Upper Mississippi River, 1975 through 1978 (EPA's unpublished data, 1978)

[illegible]	Date of Spill	Reasons for Spill	Quantity	Type of Spill	Clean-up Conducted	Water Area Affected
[illegible] Commission	1/4/75	Broken valve on transport	2000 gals.	Sewage sludge	Sanding road & scooping up	Miss. River
[illegible] Island RR	10/2/76	Derailment	1750 gals.	Diesel fuel	--	Miss. River
Amoco Oil Co.	12/18/76	Accident	3000 gals.	Gasoline	--	Miss. River
NSP Prairie Island Generating Station	Throughout the month April 1977	Turbine oil cooler leak	1200 - final est. 890 gals.	Lube oil	Boomed, cleaned up with sorbant pads	Redwing, MN on Miss. River
Koch Refining Co., Pine Bend, MN	5/29/77	Barge leak	5000 gals.	Crude oil	Skimmer, sorbant pads	Barge slip on Miss. River at Koch Refiner
Allied-Ashland Oil Inc.	10/21/77	Barge leak	1000 gals.	Crude oil	Retaining and absorbent booms and pads, buckets, etc.	Miss. River Lock & Dam No. 3 to Winona
Sun Transportation Co.	10/22/78	Barge damaged	3,600 gals.	Diesel oil #2	Same as above	R.M. 801 to Lake Pepin
Honeywell Inc.	12/10/77	Operator error - tank overfill	1000 gals.	Fuel oil #2	Mostly contained in sewers, skirted booms, absorbents	Outfall near 1180 ELK River Flat
Western Coop. Trans. Assn.	12/17/77	Truck accident	1500 gals.	Kerosine	Pumped, boomed, absorbents	University Ave. & 694 Interchange
Ingram Barge Co.	5/2/78	Barge leak	124,175 gals.	Jet fuel A.	Booms, absorbents, partial lowerings of L/D gates	R.M. 730.5-Southward
Minneapolis Parks and Recreation Board	5/12/78	Vandalism	>4000 gals.	Fuel oil #6	Booms, vacuum tank truck, absorbents	R.M. 854-857.8
Barge Sara E. Thomas	5/28/78	Leaking barge due to grounding	1000 gals.	Crude oil	--	R.M. 730.5-Southward

Because many of the major spills are related to barge activity, it is worthwhile to take a brief look at the amounts and kinds of material being transported in the GREAT I reach of the Upper Mississippi River (below lock and dam 1). Over 11 million tons of commodities are transported annually in this reach. Of this total, approximately 65 percent is grain and coal. Oil and oil products are the next largest tonnage of commodities shipped, approximately 16 percent of the total. The remaining tonnage consists of chemicals; metals and metallic ores; nonmetallic minerals; stone, clay, and cement; and other miscellaneous products. Table 7 outlines the types of commodities that have historically been transported on the Upper Mississippi River (Corps of Engineers, Performance Mileage System, 1975-1977).

Table 7 - Commodities transported on GREAT I reach of Upper Mississippi River (Corps of Engineers, Performance Mileage System)

Coal
- Coal and lignite

Petroleum and petroleum products
- Crude petroleum
- Gasoline
- Jet fuel and kerosene
- Distillate fuel oil
- Residual fuel oil
- Coke (coal and petroleum), petroleum, pitches, asphalts, naphtha, and solvents

Chemicals and related products
- Organic industrial chemicals (crude products from coal, tar, petroleum, and natural gas; dyes, organic pigments, dyeing and tanning materials, alcohols, benzene)
- Synthetics (plastic materials, synthetic rubber, synthetic fiber)
- Drugs, soap, detergent and cleaning preparations, paints, gum and wood
- Chemicals, radioactive and associated materials
- Inorganic industrial chemicals (sodium hydroxide)
- Nitrogenous chemical fertilizers (anhydrous ammonia)
- Potassic chemical fertilizers
- Phosphatic chemical fertilizers
- Other basic chemicals and basic chemical products
- Other fertilizers

Metallic ores, metal products (primary and fabricated), waste and scrap materials
- Metallic ores
- Iron ore
- Primary iron and steel products
- Fabricated metal products
- Waste and scrap materials

Nonmetallic minerals, except fuels
- Limestone flux and calcareous stone
- Sand, gravel, and crushed rock
- Phosphate rock
- Sulphur, liquid and dry
- Salt

Stone, clay, glass and concrete
- Building cement
- Lime

Fresh fish and other marine products
- Marine shells, unmanufactured

Farm products
- Corn
- Wheat
- Soybeans
- Oats
- Barley
- Rye
- Flaxseed
- Flour
- Vegetable products

Miscellaneous products
- Forest products
- Lumber and wood products
- Pulp, paper, and allied products
- Processed agricultural products (including food and kindred products and tobacco products)
- All manufactured equipment and machinery (including ordnance and accessories, machinery, electrical machinery, transportation equipment, instruments, photographic and optical goods, watches and clocks, and miscellaneous products of manufacturing)

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G. SEDIMENT & EROSION

SEDIMENT AND EROSION WORK GROUP APPENDIX

TO

GREAT RIVER ENVIRONMENTAL ACTION TEAM I FINAL REPORT

Chairmen - U.S. Department of Agriculture -
Soil Conservation Service

Gary S. LePage	1978-80
Chester A. Weldon	1975-78
Herman H. Calhoun	1975

In fulfillment of contract with the
U.S. Army Corps of Engineers
St. Paul District

FOREWORD FROM THE GREAT TEAM

This report was prepared by the Sediment and Erosion Work Group of the Great River Environmental Action Team (GREAT I). The conclusions and recommendations presented reflect the work performed by this work group only, within its specific area of expertise. Recommendations from this report will be considered in relation to other objectives for overall resource management and may be included in the final GREAT I report as considered appropriate by the GREAT I Team.

EXECUTIVE SUMMARY

Lake Pepin and the backwaters of the Mississippi River are truly one of the great environmental, recreation, and economic resources of North America. In addition to being the home for tens of thousands of species of plants and animals, the Mississippi flyway is a vital link in the life cycle of approximately three-fourths of the Nation's migratory waterfowl. Without the feeding and resting areas provided by the Mississippi River and its backwaters, many of these birds would perish.

The Sediment and Erosion Work Group has demonstrated that sediment from upland and streambank erosion poses an immediate and serious threat to the vital environmental resources of the river corridor. The work group has determined the nature and extent of the sediment problem. Solutions have been studied and the target area for action has been identified.

The work group has shown that:

1. The life expectancy of the backwater areas is limited if present rates of sedimentation are allowed to continue. Already, approximately one-quarter of the open water area present when the lock and dam system was completed has become marshland.

2. From 1895 to the present, approximately one-third of the capacity of Lake Pepin has been lost to sediment. Some areas of the lake which were once 8 to 12 feet deep are now 2 to 4 feet deep. A unique recreation and environmental resource is dying.

3. The primary source of the fine sediments which are [illegible] backwaters and filling Lake Pepin is erosion from farmlands. [illegible] source area is relatively small - approximately 9 mi[illegible] total of 51 million acres in the total drainage area.

AD-A127 210 GREAT I STUDY OF THE UPPER MISSISSIPPI RIVER TECHNICAL APPENDIXES VOLUME 4 WATER QUALITY SEDIMENT & EROSION (U) GREAT RIVER ENVIRONMENTAL ACTION TEAM SEP 80

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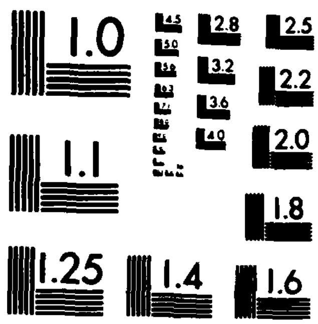

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

4. The primary source of the sand which fills the main channel is streambank erosion from tributaries. The majority of this sand comes from key sand producing tributaries. These tributaries have been identified. The greatest contributor of sand is the Chippewa River in Wisconsin. Accumulating sand sediments ultimately must be dredged to maintain the 9-foot channel. Disposal of this dredged material must be done in an environmentally sensitive manner to minimize further habitat destruction.

5. Erosion control alternatives available under existing programs and technology could reduce upland erosion by one-third in the fine sediment source areas. Such a program would cost an estimated $243 million initially and $44 million to maintain. Because existing treatment measures are able to reduce erosion only by one-third, new, more intensive erosion control practices need to be identified.

6. Preliminary feasibility studies indicate that streambank stabilization measures may reduce coarse sedimentation at some locations.

On the basis of these findings, the Sediment and Erosion Work Group recommends the following comprehensive program:

1. Accelerated Upland Land Treatment. - Existing land treatment programs should be funded to achieve the maximum erosion control possible. A goal of 80-percent land adequately protected by Soil Conservation Service standards should be established.

2. Conservation Tillage Farming. - New technology in erosion control should be investigated to refine the techniques for application in the sediment source area. A demonstration watershed should be selected and monitored to determine the potential for erosion reduction. New erosion control practices are absolutely essential to any plan designed to preserve the backwaters.

1. A navigation channel that requires periodic dredging and disposal to maintain depth for towboats.

2. Accumulation of sediments throughout the river corridor.

The SEWG (Sediment and Erosion Work Group) was formed to study the overall sedimentation problem in the river system.

The following table summarizes the planning process the work group used to study the problem of sediment and erosion in the GREAT I area. The work group coordinated its study efforts with other GREAT work groups to avoid duplication of effort. The chapters which follow point out the severity of the erosion and sedimentation problem in the Upper Mississippi River and are the basis for the work group's conclusions and recommendations for action to resolve sediment related problems.

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ATTACHMENT A - CORRESPONDENCE ON DRAFT WORK GROUP APPENDIX

ATTACHMENT B - SEDIMENT TRANSPORT IN THE UPPER MISSISSIPPI RIVER WITHIN THE ST. PAUL DISTRICT

CHAPTER I

INTRODUCTION

The Mississippi River is the largest river system in North America, gathering runoff from 31 States and 2 Canadian Provinces and draining 1.5 million square miles. On one hand, the river is a road for the transportation of agricultural products from the grain belt of the Midwest to the seaports of the South and a conduit for the fuel supplies which heat northern cities and fuel our industries. On the other hand, it is the largest environmental corridor in North America. Over 500 kinds of animals live among the diverse plant communities that thrive in and along the river.

Maintenance of the 9-foot navigation channel has required periodic dredging and disposal of bottom sediments. The accumulation of these sediments results from natural movement within the main channel, depositions at the mouth of tributary channels, and the movement of previously dredged materials. In most cases, the material dredged from the river channel has been deposited in the shallow backwater areas out of the main channel, on natural islands, or on newly created islands immediately adjacent to the channel. The disposal of dredged material has affected the valuable acreages of productive fish and wildlife habitat.

The people of the Upper Mississippi River valley have become increasingly concerned that the river be managed for the development of all of the river resources including fish and wildlife, navigation, recreation, and water quality. GREAT (the Great River Environmental Action Team), operating under the auspices of the UMRBC (Upper Mississippi River Basin Commission), was formed to represent the interests of the region in carrying out this study which will result in a plan that will provide for a balanced use of the river's resources.

GREAT

GREAT was formed in 1974 to establish a long-range management strategy for the multipurpose use of the Upper Mississippi River. The team includes representatives from the States of Iowa, Minnesota, and Wisconsin; the U.S. Department of the Interior - Fish and Wildlife Service; the U.S. Department of Agriculture - Soil Conservation Service; the U.S. Army Corps of Engineers - St. Paul District; the U.S. Department of Transportation; and the U.S. Environmental Protection Agency.

The GREAT I study area includes the head of navigation at Minneapolis/St. Paul, Minnesota, to lock and dam 10 at Guttenberg, Iowa. As Congress authorized in the 1976 Water Resources Development Act, the Great River Study was directed to investigate and study the development of a river system management plan incorporating total river resource requirements including, but not limited to, navigation, the effects of increased barge traffic, fish and wildlife, recreation, watershed management, and water quality. The organization of GREAT I includes overseeing committees and commissions which provide guidance, direction, and advice to GREAT I. Eleven functional work groups were organized to accomplish specific study objectives.

SEDIMENT AND EROSION WORK GROUP

One of the major problems identified by GREAT is the continuing sedimentation of the main channel and associated backwater areas of the river. Ironically, the lock and dam system which created many of the backwater areas also has contributed to the sedimentation process. The impoundment of the river has reduced its ability to transport sediment through the natural "flushing" process which occurs during floods and high flows. The result is:

3. <u>Chippewa River Study</u>. - Preliminary work on the Chippewa River has identified a number of potentially workable streambank erosion measures. This work should be continued.

4. <u>Shoreline Protection</u>. - The Corps of Engineers should continue its program of installing shoreline protection in the main river corridor. The Sediment and Erosion Work Group has worked with other work groups to prepare a priority list for these shoreline protection measures.

5. <u>Streambank Protection</u>. - The Corps of Engineers and the Soil Conservation Service should examine the potential for streambank protection measures on all tributaries of the Mississippi River.

6. <u>Dredged Material Stabilization</u>. - All dredged material piles should be stabilized with vegetation to prevent secondary movement.

7. <u>Sediment Monitoring</u>. - U.S. Geological Survey sediment monitoring stations should continue, and priorities should be set for establishing additional monitoring stations. Data supplied by these stations would be useful in determining priorities for erosion control.

8. <u>Diking of Backwaters</u>. - Diking off wildlife areas from the main channel should be considered as a possibility for protection from sediment damage. Diking should be done only after consideration of all the environmental and hydrologic consequences.

Time is the most important ingredient in any plan designed to deal with sedimentation in the Mississippi River. The river environment is deteriorating rapidly. Action to reverse this deterioration must be started immediately, or this part of the river, which is so important to wildlife and recreationists alike, will continue to die.

CHAPTER II

SEDIMENTATION RATES IN POOLS 4 THROUGH 10 AND SELECTED BACKWATERS

INTRODUCTION

The work group used several methods to determine the rate of sedimentation in the pools and backwaters. A series of contracts were awarded to obtain general information on the amount and extent of sedimentation in the river corridor. The results were then evaluated and used to determine the rate of sedimentation. This chapter will explain how Cs-137 (Cesium-137 - a radioactive isotope) and spud and fathometer surveys were used to determine sedimentation rates in Mississippi River pools 4 through 10 (below Lake Pepin to Guttenberg) and their backwaters. Additional sections discuss the sedimentation rate in Lake Pepin (Chapter III) and recent (1939-1973) loss of aquatic habitat from sedimentation in pools 5 through 10 (Chapter V).

CS-137 SEDIMENT DATING TECHNIQUE

The work group contracted with the SEA (Science and Education Administration) Sedimentation Lab, Oxford, Mississippi, to determine the amounts and rates of sediment deposition in pools 4 through 10. SEA used the Cs-137 technique it developed.

The following abstract (McHenry and Ritchie, 1975) explains the concept of the dating method. In-depth information can be found in: (1) McHenry, Ritchie, and Gill, 1963; and (2) Ritchie and McHenry, 1973.

Radioisotopes have been introduced into the atmosphere by nuclear bomb test explosions. Wind and water have distributed this fallout over the earth's surface, tagging the surface soil with identifiable and unique tracers.

Cs-137 is of special interest because of its abundance and properties. It is strongly absorbed by the finer soil particles, inorganic or organic. In addition, it has an energetic gamma emission which makes it easier to detect and quantify. Thus, when attached to fine soil particles, Cs-137 facilitates the tracing of those labeled soil particles in the sedimentation process.

If the fallout Cs-137 is deposited uniformly over a watershed, both surface soils and existing surface sediments should receive equal amounts of fallout. If erosion occurs, some Cs-137 labeled soil particles will be removed and deposited downstream as sediment. If this is a frequent process during the years when Cs-137 fallout is large, the resulting sediment will be labeled with Cs-137. Where soils are actively eroding, little or no Cs-137 will remain and, as the fall-out rate decreases, the annual erosion will contain a lesser amount of Cs-137 labeled particles. Thus, the accumulating sediment profile should reflect the yearly intensity of fallout on the watershed.

The ..ak radioactive fallout years were 1962-1964 when the Russians conducted nuclear tests. A smaller, definable fallout peak occurred in 1957-1959 as a result of American tests. Since 1963, the Cs-137 fallout rate has steadily decreased, except for a very minor increase after 1971 resulting from Chinese and French testing. If the accumulating sediment profile is undisturbed and sediment inflow is regular, the profile will exhibit a large peak concentration corresponding to the 1962-1964 fallout and a secondary peak for the earlier 1957-1959 period. Cs-137 in a sediment profile indicates the sediment was deposited since 1954; a sharp peak concentration indicates that sediment was deposited in 1963-1964. Thus, the age and rate of recent sedimentation can be estimated.

STUDY DESCRIPTION

In 1975, the SEA started to sample sediments in pools 4 through 10 to obtain general sedimentation rate information. Because Cs-137 is strongly attached only to fine sediments, sampling sites were selected in those areas where fine sediments are deposited (typically the backwaters and lower reaches of each pool). Samples were taken by spud survey from 47 locations scattered throughout the study area (McHenry and Ritchie, 1975).

In 1976-1977, the work group contracted with SEA to conduct follow-up extensive sedimentation rate studies for pools 7, 8, and 9. In addition to Cs-137 surveys, pools 8 and 9 were measured with a recording fathometer to determine bottom contours along established cross sections. Pool 7 (Lake Onalaska) contour data were already available (Claflin, 1977). Fathometer results were plotted and compared with 1937 preclosure contour maps to detect postimpoundment sediment accumulations.

The fathometer and spud surveys were useful for computing recent sedimentation. The spud survey produced a sediment core sample that could be analyzed on the basis of sediment consolidation. Recently accumulated layers of sediment (postimpoundment) would have the least density. The spud survey could, therefore, help reveal the amount of sediment deposited since impoundment.

By comparing the results of the Cs-137, spud, and fathometer surveys, a representative sedimentation rate could be calculated. Because sampling or surveys were site selective and widely dispersed over the study area, the accumulated amount of sediment is an estimate. A general conclusion, however, can be reached on the amount and extent of sedimentation.

Because Cs-137 tracing depends on presence of fine sediment, sieve analysis testing was performed on all samples taken to determine if fine sediments were present. This was particularly important in the recent layers of sediment where the tracer isotope is expected to be present. Particle size data were also useful for determining the source of sediment (that is, product of upland or streambank erosion).

The sedimentation rate is indicative of only fine particle accumulation which takes place in lower current velocities normally found in the backwaters or lower reaches of each pool. The source of these sediments is primarily upland erosion. Deposition of coarse sediment (sand) is a separate problem on the river because of its primary source (streambank erosion) and because transport of sand sediment is usually confined to within the main channel or main channel border. Erosion and deposition of coarse sediment is further discussed in Chapter IV.

STUDY RESULTS

Although a large number of data have been collected, tabulated, and illustrated regarding the amount of accumulated sediments deposited in backwaters and low-flow pool areas, the most important product of the studies described in this chapter is the estimate of sedimentation rates. The following tables and narrative summarize that information.

Calculated sediment accumulation rates, pools 4 through 10[1]

Pool	Maximum depth of Cs-137 deposition (centimeters)	Estimated rate of sedimentation (centimeters per year) Since 1955	1963-1975
4	50	2.5	2.5
6	70	3.5	4.2
8	60	3.0	4.2
9	70	3.5	3.3
10	70	3.5	4.2

(1) From McHenry, Ritchie, and Verdon, 1976.

Sediment accumulation rates in pool 7[1]

Area	Number of profiles	Average annual sediment accumulation rates (centimeters per year) 1954-1977[2]	1938-1976[3]
1	0	-	0.7
2	2	2.15	1.0
3	2	1.75	2.7
4	2	1.10	1.5
5	2	1.55	2.3
6	4	1.72	1.7
7	3	1.90	1.6
8	3	2.47	1.6

(1) From McHenry and Ritchie, 1978.
(2) Using Cs-137 method.
(3) From Claflin, 1977.

Sediment accumulation rates in pool 8[1]

Cross section	River mile	Average annual sedimentation rate (centimeters per year) Fathometer (1937-1977)	Spud (1937-1977)	Cs-137 1957-1964	Cs-137 1964-1977	Cs-137 1954-1977
1	681.8	0.60	1.28	1.33	2.05	1.74
2	682.8	1.14	1.30	1.00	1.28	1.01
3	684.0	0.24	1.84	2.00	3.07	2.61
4	685.4	0.72	0.74	1.00	1.54	1.30
5	686.9	0.62	1.07	2.33	2.82	2.61
6	688.4	0.50	0.88	1.67	2.31	2.03
Average	-	0.64	1.18	1.56	2.18	1.88

(1) From McHenry, Ritchie, and Cooper, 1978.

Sediment accumulation rates in pool 9 (1)

Cross section	River mile	Average annual sedimentation rate (centimeters per year): Fathometer (1937-1976): 500-foot (2)	Fathometer (1937-1976): Planimeter (3)	Spud (1937-1976)	Cs-137: 1954-1964	Cs-137: 1964-1976	Cs-137: 1954-1976
1	648.7	0.5	0.5	1.4	1.0	1.9	1.5
2	649.4	0.4	0.4	1.1	1.0	2.7	2.0
3	651.1	0.8	0.8	1.0	2.0	3.3	2.7
4	653.3	0.5	0.5	2.0	3.3	4.7	4.1
5	654.5	0.5	0.3	1.3	2.4	2.7	2.6
6	655.5	0.7	0.6	1.0	2.0	1.9	1.9
7	656.0	0.0	0.1	0.2	3.0	2.1	2.5
8	657.0	0.2	0.2	0.6	2.5	1.7	2.0
9	657.8	0.5	0.3	1.0	2.0	0.8	1.4
10	659.6	0.6	0.7	0.6	3.0	0.8	1.8
11	661.0	0.6	0.9	0.7	2.6	3.1	2.9
Average	-	0.5	0.5	1.0	2.2	2.3	2.3

(1) From McHenry and Ritchie, 1977.
(2) Determined by sampling cross-section plots at 500-foot intervals.
(3) Determined by planimetering area between 1937 and 1976 bottom contours on cross-section plots.

More complete information addressing sampling locations, particle size analysis and correlation, and Cs-137 concentration is contained in the references given for the tables.

The sediment rates in the preceding tables make it clear that all reaches of the study area are rapidly aggrading. Because different methods were used and sampling was fragmentary, the rates are somewhat conflicting. However, all of the data supports the conclusion that rapid sedimentation is taking place. Each method used (fathometer, spud, and Cs-137) may, by itself, be insufficient to make exact accumulation estimates, but when combined all methods support the same conclusion. The Cs-137 determinations tend to be the highest and the fathometer results the lowest. This was expected because the Cs-137 estimates were based on 10-centimeter sample increments (therefore 0 to 10 centimeters of sediment containing a given amount of Cs-137 was tabulated at 10-centimeter depth)(Ritchie, McHenry, Gill, 1972).

Calculated sedimentation rates vary by pool and location. Influencing factors are rate of water flow, concentration of suspended sediment, and location of tributaries.

Sedimentation rates indicate that a very real and urgent problem exists in those areas where fine sediments are depositing. Almost all the sampling sites are relatively shallow, slack-water areas where water depth is less than 5 meters. Few of the backwaters exceed a depth of 3 meters. A sedimentation rate of 2-3 centimeters per year is equivalent to 2-3 meters in a century. Thus, the problem of sedimentation must be resolved quickly or the backwater lakes and pools of the study area will cease to function as viable aquatic or semiaquatic habitats (McHenry and Ritchie, 1975).

CONCLUSION

The life expectancy of the backwater areas is limited if the present sediment flow continues. If the present rate of sedimentation is allowed to continue, most of the open water areas of the backwater lakes will succeed to marshland within the next century. Prevention of sediment production at the source is the only solution for extending the existence of the Mississippi River pools and backwater lakes. Soil conservation practices need to be applied to all potential sediment source areas.

CHAPTER III

SEDIMENTATION IN LAKE PEPIN

INTRODUCTION

Lake Pepin is truly one of the great natural resources of the Upper Mississippi River valley. This 22-mile long stretch of the Mississippi River corridor is the only naturally occurring lake in the study area. Lake Pepin has attracted a good deal of public interest because of its importance as a recreation resource. People who have lived in the Lake Pepin area for a long time have noticed physical changes in the lake. Those who have hunted and fished Lake Pepin are aware of areas they used to be able to cross in a boat that are now becoming clogged with emergent vegetation. In response to this public interest, the SEWG set out to determine the extent and nature of the problem in Lake Pepin. The work group had these objectives:

1. To determine the overall rate of sedimentation.

2. To identify the specific areas where sedimentation was occurring and to measure the extent of sedimentation in each area.

3. To determine the types of material present in the sediment.

4. To identify the source of the sediment.

5. To determine the need for corrective measures.

To properly address these objectives, the work group initiated studies to determine the nature and extent of the sediment problem in Lake Pepin.

RE-SOUNDING OF LAKE PEPIN

In 1895, the Corps of Engineers conducted a sounding of Lake Pepin. Records of this early sounding were located and an 1895 contour map of Lake Pepin was prepared by the work group. This map provides an excellent base line for measuring the "evolution" of Lake Pepin.

A 1976 contour map of Lake Pepin was prepared from data obtained through a new sounding of Lake Pepin. Even a casual comparison of the two maps shows the remarkable changes that have occurred between the two soundings. In 1895, large areas of open water were at the head of Lake Pepin. In 1976, almost no deep water areas remained in the Bay City, Wisconsin, end of Lake Pepin. While the comparisons at the head of Lake Pepin are most dramatic, one can pick almost any area of the lake, compare the two maps, and find that the lake has shallowed.

The map on page 20 reveals those changes caused by the sedimentation in Lake Pepin. This map was prepared by comparing the two contour maps and delineating the areas of sedimentation by depth of sediment deposits. The message is clear - Lake Pepin is filling in. In some areas, sedimentation is rapid. In the upstream end of Lake Pepin, the sedimentation rate exceeds 1 inch per year in many places. The reason for the greater rate of sedimentation at the upstream end of Lake Pepin is that this is the place where the rapidly moving waters of the river channel first meet the still waters of the lake. The rate of sedimentation decreases as one proceeds downstream through the lake. The large differential in sedimentation rates between the upstream and downstream end of Lake Pepin indicates that the sediment is probably coming from upland erosion sources. If the sediments were primarily limnic materials (lake originated), the sedimentation rate in the lake would be much more uniform.

SEDIMENT RATING

To get a more thorough picture of the sedimentation process in Lake Pepin, several other studies were initiated to determine the rates of sedimentation from 1960 to the present, sediment densities, and particle size distribution, and eventually to corroborate the data and conclusions from the two soundings of Lake Pepin. These studies were performed by the SEA Sedimentation Laboratory. Five ranges were selected across Lake Pepin. Each range was divided to equally space five boring sites across the lake. The drilling operation was conducted during the winter through the ice. The samples collected for Cs-137 analysis (McHenry et al., 1963; Ritchie et al., 1973) were taken to the laboratory where they were processed. Cs-137 concentrations and particle size distributions were determined. For discussion of the rationale and procedure used in the Cs-137 dating process, please refer to the section on fine grain sedimentation in the major pools.

SEDIMENT DENSITY

The SEA conducted a sediment density survey in cooperation with the St. Paul District, Corps of Engineers, to determine the consolidation of sediment layers. Sediment profiles were surveyed on the same ranges as established for sampling through the ice. On each range, sampling sites were located as close to the boring sites as possible. A raft was positioned on range and a heavy spud dropped. The spud held the raft securely on range while measurements were made. The probe was lowered vertically to a depth short of the indicated water depth. Standard or water density readings were made and then the probe was lowered in half-foot increments and readings of density made. As the probe was lowered into the sediment, the mass increased. The process continued until the probe could not be pushed farther into the sediment. A maximum of 9.5 feet of sediment was penetrated.

BORING ANALYSIS

As was also discovered in the comparison of the two soundings of Lake Pepin, the sediment sampling indicated that the depth of sediment accumulated decreased downstream through the lake averaging approximately 180 centimeters on the upstream range and 130 centimeters on the downstream range. The table on page 8 shows the summary of the Cs-137 concentration data by depth and range. These data indicate increased amounts of Cs-137 in the upstream sediment profile. Considerably lesser amounts of Cs-137 were found in the lower end of the lake. The data demonstrate that a considerably greater rate of recent sedimentation accumulation has occurred in the upper end of the lake and that the sediment in the upper end of the lake results from upland erosion. Further evidence is the fact that not only are the concentrations of Cs-137 per unit depth greater in the upstream profiles, but the depth of inclusion of Cs-137 in the profile is greater.

The estimates of sedimentation from 1895 to 1954 were 2.5, 2.3, and 2.7 centimeters per year for the stations at the upstream end of the lake and 2.4 and 1.8 centimeters per year at the downstream stations. The average sedimentation rates in Lake Pepin since 1954 are, therefore, somewhat less than for the period 1895 to 1954.

RESULTS OF STUDIES

Despite the apparent recent decrease in the rates of sedimentation in Lake Pepin, these rates are still high enough to be of concern. Deposition of 2 centimeters of sediment per year would be equivalent to a loss of 2 meters of water storage capacity in a century. This was the loss experienced during the past century. Continuation of this rate of sedimentation would transform much of the upper end of Lake Pepin into a marsh within three generations (McHenry et al., 1977).

The measurements of particle-size distribution indicate the sediments in all sampled profiles were essentially silty clays. The percentage of 2-micron clay increased somewhat downstream in the lake. The farthest upstream range sampled in this study is below the delta area in the lake because little sand has been carried this far into the lake. This indicates that the carrying capacity for coarse-grained sediments decreases as the current dissipates.

Sediment density measurements were made on all sites. Sediment densities, in the profile depths measured, are low, indicating high clay content. Densities increase with depth indicating compaction with passage of time.

The sediment profiles are very consistent, with extremely low densities at the surface increasing to 30 to 35 pounds per cubic foot in the lower end of the lake at about 8 feet and to 40 to 45 pounds per cubic foot at 7 feet in the upper end. This pattern indicates a long period of sediment accumulation with some segregation of the fines and their concentration in the lower lake.

The depth of sediment accumulated at the downstream end of the lake since 1895 is between 4 and 5 feet. No breaks or discontinuities are in the measured density values for the three deep profiles. It does not appear that the nature of the sedimentation process has changed since 1954, 1895, or earlier. If the accumulation of sediment from 1895 to the present is represented by the top 4 or 5 feet, the sediment density profiles probably go back to around 1800. On the upstream end of the lake the depth of sediment accumulated since 1895 is between 5 and 6 feet. The pattern of density is regular, increasing with depth and showing no particular change in the evaluation.

The sediments at the surface now with densities of 15 to 20 pounds per cubic foot will consolidate over the next 70 to 80 years to a density of 30 pounds per cubic foot and in 150 years to 38 to 40 pounds per cubic foot. This would mean a reduction in volume with time, estimated to be 33 percent in 75 years and 50 percent in 150 years. When considering the probable loss of water storage capacity in the lake resulting from sediment accumulation, the factor of compaction should be considered. Compaction will lessen the volume of water storage capacity lost.

An area of concern frequently mentioned in public meetings was sewage effluent from the Minneapolis/St. Paul area and the effect that organic material from this effluent has on the sedimentation rate in Lake Pepin. The percentage of organic matter contained in the samples is very similar to the percentage of organic material in surrounding upland soil - between 4 and 6 percent. These data seem to indicate that organic material from the Twin Cities sewage effluent is largely oxidized before it reaches Lake Pepin. In fact, the organic matter content of the sediment samples between the upstream and downstream end of the lake differs little. Thus, organic material from Twin Cities sewage effluent is not a significant factor in the sedimentation of the lake. Industrial and other inorganic pollutants may originate from upstream sewage effluent. This matter was addressed by the GREAT I Water Quality Work Group.

CONCLUSIONS

The rates of shoreline sediment accumulation in Lake Pepin have changed very little since 1895. The sediment density profile data indicate that the sedimentation pattern before 1895, perhaps back to the early 1800's, is very similar to that since 1895. No information exists on the rates of sedimentation prior to 1895, but the consolidation process appears uninterrupted. From 1964 to 1977, the sedimentation rate decreased from about 2.5 centimeters per year

at river mile 782 to less than 0.5 centimeter per year downriver at river mile 767. From 1956 to 1964, the corresponding accumulation values are 2 centimeters and 0.5 centimeter per year. From 1895 to 1954, the calculated sediment deposition rates are approximately 2.5 and 2.1 centimeters per year, upper and lower ranges, respectively. These estimates of sedimentation rates are based on volumetric measurements. If corrections for differences in sediment density are made (the older sediments are generally more dense), the present sedimentation rates are less than those from 1895 to 1954. Throughout the area of the lake sampled, the sediments are silty clay in texture. The percentage of clay tends to increase downstream in the lake.

It is difficult to draw conclusions as to the reasons for the slight differences in sediment rates both in terms of time of deposition and location (upstream and downstream). In the early period of the study (1895 to the 1940's), the critical sediments source area identified in Chapter VI was farmed less intensively in terms of percentage of cropland. However, conservation practices during this time period were largely lacking. In the later period of the study, the farmland in the critical sediment source area has been cropped more intensively. However, better conservation practices were present. It is probable that the slight decreases in sedimentation rate actually indicate a larger effect of the increased rates of conservation practices applied because a decrease in sediment accumulation has occurred in spite of the great increase in the amount of land in the critical sediment source area which is cultivated (particularly in row crops).

Although the present rates of sediment accumulation are no more and probably less than the average for the past 80 years, these rates are great enough to be of concern. The Cs-137 sediment dating study and the comparison of the bottom contour maps indicate that the upper end of Lake Pepin is seriously threatened by sediment and its environmental value will probably be lost in the very near future. Environmental degradation of the middle and lower parts of the lake will occur over

a greater period of time. Sediment studies clearly indicate progressively larger rates of sedimentation as one proceeds upstream through the lake. This observation, coupled with the particle size analysis which indicates that the sediment is largely silt and clay, points to the fact that the source of sediment in the lake is upland erosion. Therefore, the focus of any program to halt the sedimentation of Lake Pepin must be directed toward curtailing upland erosion. Clearly, increased soil and water conservation in the sediment source area represent the only long-term hope for saving Lake Pepin.

CHAPTER IV

CHIPPEWA RIVER EROSION AND SEDIMENTATION STUDY

INTRODUCTION

The SEWG identified the Chippewa River as a major source of sand in the Upper Mississippi River system and selected the Chippewa River for intensive study. The work group also recommended that the Corps of Engineers select the Chippewa River for an erosion control demonstration project authorized by the Streambank Erosion Control Evaluation and Demonstration Act of 1974.

The purpose of the demonstration program is to illustrate inexpensive and innovative bank protection measures. During the first year of the 5-year program, erosion control measures will be installed. Their effectiveness will be monitored for the remainder of the program. Construction on the Chippewa River is scheduled to be completed in the fall of 1980.

GREAT has placed major emphasis on preparing a long-term channel maintenance plan, including predicting dredging requirements. Therefore, any knowledge gained from the Chippewa River demonstration project will apply directly to future modifications of the maintenance plan.

The results of the project will also be used in the Chippewa River erosion and sedimentation feasibility study being conducted under GREAT. Thus, it is desirable that the successes or failures of the project be known before the final feasibility report is completed. Preliminary results of the feasibility study are included in the GREAT I report. The feasibility study, however, will be completed under the authority of the 11 December 1969 resolution of the House of Representatives Committee on Public Works which requested a study of water resource problems in the Chippewa River basin. The final feasibility report is scheduled for 1986.

The demonstration proje-t and feasibility study will provide nportant information to the GREAT study. Their dual purpose is to:

1. Determine the feasibility of implemented control measures nd the extent that erosion and resultant deposition can be reduced.

2. Act as a pilot project to gain information about erosion and edimentation problems in other critical tributary and watershed areas.

HE EROSION PROBLEM

Soil erosion has been a problem in the Chippewa River basin for many years, particularly in the lower reaches downstream from Eau Claire, Wisconsin. Farms in the hilly areas with deeply entrenched drainage courses are the most seriously affected. In 1933, the Federal Government initiated a nationwide erosion control program carried out by Civilian Conservation Corps camps under the technical guidance of the Department of Agriculture. Soil conservation activities were initiated in the Chippewa River basin in 1933 and have continued with increasing coverage.

Methods of application have changed. Since 1939, the counties have been organized into soil conservation districts under a 1937 Enabling Act of the Wisconsin Legislature. The Soil Conservation Service of the Department of Agriculture provides the planning, engineering, and guidance under the provisions of Public Law 46 and other acts.

"The Natural Resources of Wisconsin" dated December 1956 shows that, as of 30 June 1954, there were 730,000 acres in 4,830 farms in the basin under soil conservation programs. This work is being accelerated, according to the State Conservationist in Madison, Wisconsin.

Bank erosion and resulting deposition have long been recognized as severe problems along the Chippewa River especially in the lower reaches below Eau Claire. Erosion of riverbanks composed of sand and fine gravel undermines the toe of the bank causing shore material to slide into the channel thereby resulting in loss of floodplain land. More crucial, however, is the effect that the eroded material has as it is swept downstream and redeposited.

Water and sediment moving through the Mississippi and Chippewa Rivers are affected by lock and dam 4. At low and intermediate flows, the dam raises the pool level above the natural river level. This increases the flow depth in pool 4 of the Upper Mississippi and the lower Chippewa Rivers. The backwater of pool 4 can affect the Chippewa River up to 6 miles above its mouth, decreasing the ability of this river reach to transport sediment. The result is deposition in the lower reach of the Chippewa River at low and intermediate flows.

With flood flows, the gates at lock and dam 4 are opened and flow conditions approach the natural river state. During floods, the sediment deposited on the Chippewa River bed during periods of low and intermediate flow is flushed downstream to the Mississippi River. The amount often exceeds the sediment transport capacity of the Mississippi River. This results in deposition in pool 4 below Lake Pepin and to a lesser degree farther downstream. It is these areas of excessive deposition that require recurrent dredging to maintain the navigation channel. The erosion and deposition depends greatly on the relative magnitudes of the Mississippi and Chippewa River flows.

Dredging records for the pool 4 reach in the Upper Mississippi River indicate that the most troublesome crossings that require frequent dredging are between river miles 762.4 and 763.8 near the mouth of the Chippewa River, between river miles 758.9 and 759.6 above Hershey (Crats) Island, and between river miles 757.1 and 758 near Teepeeota Point. The dredged volumes in these three reaches were 2,120,000, 3,188,000, and 2,473,000 cubic yards, respectively, between 1936 and 1972. These reaches are straight and the flow is divided by alluvial islands. The dredging in these reaches accounted for about 78 percent of the total dredging in pool 4 downstream of Lake Pepin between 1936 and 1972. The total dredged volume reported in this river reach was 9,913,000 cubic yards during this time. Assuming that the unit weight of the dredged material was 100 pounds per cubic foot, the bed material dredged from this river reach averaged about 360,000 tons per year.

It has been verified that the Chippewa River is the major source of coarse sediment contributing to dredging needs in pool 4. By virtue of its comparatively steep gradient, high velocity, and easily eroded banks, the Chippewa

River transports more sediment per unit volume of water than the Mississippi River. It carries several hundred thousand cubic yards of coarse material to the Mississippi River each year. The total weight of this coarse material is about 600,000 tons in an average year. Much of this material is dredged from the Mississippi River to maintain the 9-foot navigation channel. It is estimated that the Chippewa River is responsible for about 20 percent of all maintenance dredging along the Mississippi River within the St. Paul District. The annual dredged amount in the lower pool 4 reach is about 40 percent of the Chippewa River sediment inflow in an average year. Comparing this value with the sediment transport capacity of pool 4 at lock and dam 4 main stem indicates that most of the Chippewa River sediment dropped out in the lower pool 4 main stem has to be dredged to maintain the navigation channel. The 60-percent of Chippewa River sediment transported through lock and dam 4 reaches as far as pool 5A and affects the navigation channel there. A portion of this sediment must be dredged to maintain the navigation channel in the downstream pools.

The practice of overdepth and overwidth dredging plays an important role affecting the annual dredging quantities. Other factors that influence dredging requirements include:

1. Extended periods of abnormally low flow where lack of water in the system becomes a controlling factor.

2. Extended periods of unusually high flow.

3. Effectiveness and efficiency of dredging operations.

Before GREAT was formed, the Corps maintained the navigation channel in the most economical manner, giving consideration to environmental damage only when alternatives within plant capability at low cost were available. In addition to direct covering of productive wildlife habitat, seasonal high flows cause secondary movement of sand into adjacent side channel openings, backwaters, and other habitat areas. Since GREAT was established, an on-site inspection team composed of agencies participating in GREAT has worked with the Corps to select material placement sites that would cause minimal environmental damage and comply with Federal and State regulations.

NEEDS AND DESIRES

The overriding water resource need of the lower Chippewa River basin appears to be control of streambank and streambed erosion.

DEVELOPING A PLAN (PLAN FORMULATION)

The purpose of plan formulation is to develop a plan to provide the best use of resources to meet the identified needs of the basin. Two stages of plan formulation have been completed for this report. The first stage was to determine preliminary feasibility of a complete range of alternatives. The second stage is an iteration of the first concentrating on the evaluation of alternatives found most feasible. A third stage of plan development will follow. This stage will involve the selection of a final plan of improvement which will be recommended to Congress for implementation. As stated earlier, however, this stage will be postponed until after results of the erosion demonstration program are known.

Stage I Formulation

The intent of preliminary feasibility formulation is to identify, evaluate, and compare alternatives with a view toward feasibility and acceptability. A set of specific planning objectives guided this initial stage in the formulation process. These specific planning objectives are components of the national objectives of NED (national economic development) and EQ (environmental quality) and include:

1. Preserving the quality of the existing riverine environment to the maximum extent possible and enhancing the environmental and recreational potential of the rivers, lakes, and reservoirs in the Chippewa River basin.

2. Providing erosion control measures along the lower Chippewa River which recognize land losses and emphasize sediment reductions to be realized downstream along the Chippewa River and Mississippi River navigation channel.

In addition to the above specific planning objectives, various indirect social and environmental constraints guided development and acceptability of the alternatives. These included:

1. Developing a plan that is responsive and acceptable to the local people's desires and needs.

2. Enhancing the social well-being of the area.

3. Recognizing the national significance of the Chippewa River Bottoms, Buffalo County, Wisconsin, as a site included in the National Registry of Natural Landmarks, and potential landmarks (Nelson-Trevino Bottoms and Tiffany Bottoms Wilderness Area).

Possible Solutions. - Appropriate alternatives to meet identified study area needs were considered. Erosion and sediment reduction appear to be the most pressing problems along the lower Chippewa River. Possible solutions have been incorporated with the alternatives developed principally to meet the traditional Corps mission.

Alternatives Studied. - Alternatives considered to reduce erosion along the Chippewa River and decrease the flow of sediment from the Chippewa River to the Mississippi River include:

Alternative 1. - Increase storage of existing flood control/power dams in the Chippewa River basin to reduce downstream flood discharges.

Alternative 2. - Install a sediment trap on the lower end of the Chippewa River.

Alternative 3. - Establish a meander pattern in the Chippewa River below Durand, Wisconsin.

Alternative 4. - Divert a portion of the Chippewa River flow into Lake Pepin.

Alternative 5. - Divert a portion of the Chippewa River into a sediment basin formed by the backwater of pool 4.

Alternative 6. - Install a low-head dam at the lower end of the Chippewa River.

Alternative 7. - Install a series of low-head dams on the lower Chippewa River to reduce channel gradient.

Alternative 8. - Use streambank erosion controls.

Selecting Alternatives for Further Analysis. - Selection of alternatives for further analysis in stage II formulation was based on the need for the best uses of natural and man-made resources in the basin. Alternatives were analyzed with respect to increasing national economic efficiency and enhancing environmental quality. Satisfying specific objectives relating to the needs and desires of the people in the basin guided initial selection of alternatives. The benefit-cost ratio, principle of net benefits maximization, and effects assessments with and without project conditions over the project life were the main tools used in evaluating the alternatives.

The alternatives analyzed all satisfy specific objectives to some degree. However, several of the alternatives have severe adverse impacts on these objectives or do not satisfy the constraints of the study and, thus, are not viable. Alternatives 3 (establish meander pattern), 4 (Lake Pepin diversion), and 5 (Buffalo Slough diversion) are not locally acceptable and would not preserve the Chippewa River Bottoms Natural Landmark and the other prospective landmark areas. These three, along with alternative 1 (increase upstream reservoir storage), rate low in preserving the riverine environment in the study area. None of the alternatives significantly benefit recreation but could perhaps be made to better satisfy this objective through additional measures. Flood control can best be solved by local projects designed specifically for that purpose.

The NED objective is satisfied by alternatives 5 through 8. These alternatives display positive net monetary benefits. Alternative 2 (sediment trap) could become economically attractive if a beneficial use for material dredged from the "trap" is found. Alternatives 1 (increase upstream reservoir storage), 3 (establish meander pattern), 4 (Lake Pepin diversion), and 5 (Buffalo Slough diversion) are not economically feasible and any scale of development would not make them feasible.

Environmental quality aspects of the alternatives range from significant enhancement of the environment to significant adverse impacts. Alternatives 1, 3, 4, and 5 would have significant net adverse impacts.

From the above discussion and the screening that was performed in Stage I, it is evident that the following alternatives warranted further investigation:

- Alternative 2 - Sediment trap.

- Alternative 6 - Low-head dam above the mouth of the Chippewa River.

- Alternative 8 - Streambank erosion control.

Stage II Formulation

Stage II is an iteration of Stage I. The intent of Stage II was to:

1. Further examine the alternatives identified in Stage I as warranting additional study.

2. Combine studied alternatives to formulate several plans that can be studied to implementation detail during Stage III.

The Stage II studies consisted of the physical and environmental evaluation of erosion and sedimentation control measures identified in Stage I with a view toward combining and adding to these measures to develop a plan which

(1) emphasizes national economic development (NED), (2) emphasizes environmental quality (EQ), (3) makes the best contribution to both national objectives (NED and EQ), and (4) is largely nonstructural.

To develop these plans and achieve optimum benefits, the following data were assembled:

1. Physical environment: flow discharges, sediment discharges, stages, hydrographic survey maps, soil maps, properties of bed and bank materials.

2. Biological environment: vegetation, mammals, birds, reptiles and amphibians, fish, benthic macroinvertebrates, phytoplankton, zooplankton, and rare and endangered species.

3. Socioeconomic environment: population, income, agriculture, employment, and recreation.

4. Cultural environment: archeological and historic sites. These data were analyzed to determine resource profiles of existing conditions and project resources to the base year (1990).

The future physical environment has been projected over the 50-year study period (1990-2040). The associated changes in the biological and socioeconomic environment were determined. These without-project conditions served as the base line to which plans for water and land-related resource improvements were compared. Because the predictions were based on existing data, and very little fieldwork was conducted, some degree of uncertainty is built into the evaluation and projections.

A mathematical model of the Chippewa River network system was used to determine the river's physical response to various plans. The effects of each proposed project plan on the terrestrial and aquatic systems were evaluated. Potential losses, costs, and benefits were assessed by evaluating the impacts of each alternative on socioeconomic factors. By comparing the river environment of the lower Chippewa River with and without project conditions, the NED, EQ, combinat' and nonstructural plans were developed and improved.

Plans Considered

The following plans were investigated in Stage II:

1. Establish stream erosion controls and dredge a sediment trap at the lower end of the Chippewa River.

2. Establish stream erosion controls and construct a low-head dam at the lower end of the Chippewa River.

3. Construct a low-head dam at the Chippewa River mouth and dredge behind the dam.

4. Establish stream erosion controls, construct a low-head dam at the Chippewa River mouth with dredging behind the dam.

5. Nonstructural plans.

    a. Dredge a sediment trap at the lower end of the Chippewa River.

    b. Increase storage of existing dams in the Chippewa River basin.

The impacts of the various plans on the physical, biological, and socio-economic environments are discussed in the following paragraphs.

1. Establish Streambank Erosion Controls and Dredge Sediment Trap at the Lower End of the Chippewa River.

A geomorphic study of the Chippewa River indicates that the sediment transported to the Mississippi River originates mainly from erosion of the channel and banks below Eau Claire. The most efficient way to reduce the sediment supply and save the property from erosion is to stabilize the banks and/or deflect the flow from erodible areas. High banks subjected to significant erosion were identified. They include the banks along the right bank of Ninemile Slough (near river mile 20), opposite Happy Island (near river mile 33), and upstream of Elk Creek (near river mile 46). These banks are more than 100 feet high. They are being undermined at the toe by the flow, causing slides into the channel. Many low banks along the Chippewa River below Eau Claire are also being eroded.

Various channel modifications and structures have been developed to control river flow alignment and stabilize the riverbanks. The proposed erosion control measures to stabilize the Chippewa River channel were presented in detail in the report by Simons and Chen (1978). Some of these and other erosion control structures are being included in the Demonstration Shoreline Erosion Control Project on the Chippewa River, Pepin and Dunn Counties, Wisconsin, developed in response to Section 32 of the Water Resource Development Act of 1974, Public Law 93-251. The major objective of the project is to develop inexpensive erosion control measures and evaluate their effectiveness. The structures that are effective will be used in this alternative to protect the Chippewa River banks. The overall average construction cost for an erosion control structure, based on demonstration project estimates, is about $35 per linear foot of bank.

Protection of the banks would not immediately reduce the sediment supply to the Mississippi River; in the long run, it would reduce the Chippewa sediment supply only about 15 percent. Supplemental controls would be required if the sediment supply were to be reduced immediately. The dredging of a sediment trap would be a good supplemental measure.

The geometric changes in the Chippewa River after implementation of this alternative measure would be caused mainly by the streambank erosion controls. Dredging a sediment trap would affect only the lower end of the Chippewa River at and downstream of the trap.

Assuming that the protective works were implemented at the nine most seriously eroding sites (which total about 5 miles), and that these measures effectively prevented the banks from further erosion, the floodplain area saved from erosion would total 30 acres - about 25 percent less than the eroded area estimated for the without-project condition. With the exception of Yellow Bank (near river mile 20), where agricultural lands are being eroded, the other sites involve forest lands. The construction cost for protecting these sites would be from $0.5 to $1 million based on the unit cost of $35 per linear foot of bank. Costs could be substantially higher for more conventional erosion protection if the demonstration project measures proved ineffective.

Bank erosion below Eau Claire provides about 35 percent of the sediment discharge in the Chippewa River. If the banks were protected, the bed degradation would increase to satisfy the transport capacity of the river. However, armoring would gradually develop, reducing the degradation rate and limiting the total degradation. The overall bed degradation between 1990 and 2040 is estimated to be about 0.4 foot compared with 0.2 foot for the without-project condition. The channel slope would be decreased by 1 percent. Dredging a sediment trap would affect the bed contour of the dredge cut.

The effects of bank protection on the sediment supply rate from the Chippewa River to the Mississippi River would increase with time. After 50 years, the sediment supply would be reduced by 15 percent compared to the without project condition if all the eroded banks were protected. If only the nine major erosion sites were protected, the sediment supply would be reduced about 10 percent. Dredging a sediment trap at the lower end of the Chippewa River would reduce the Chippewa River sediment supply by the weight of the dredged material from the sediment trap. The combined effects of protecting the major erosion sites and dredging a trap 500 feet wide, 2,100 feet long, and 3 feet deep every year would reduce the Chippewa River sediment supply about 40 percent, or from about 410,000 tons per year (without project conditions) to about 230,000 tons per year by 2040. The combined effects, including doubling the size of the dredged trap, would reduce the Chippewa River sediment supply about two-thirds, or from about 410,000 tons per year (without project conditions) to about 130,000 tons per year by 2040. This large reduction in the Chippewa River sediment supply to the Mississippi River would degrade the Mississippi River downstream of the Chippewa River confluence and reduce dredging requirements in pool 4 and downstream pools. However, bed degradation could reduce the riverbank stability adjacent to the Chippewa River confluence and require bank protection.

Because of excessive sediment deposition in some localized areas, bank protection and dredging of a sediment trap cannot be expected to reduce the dredging requirement in pool 4 by 100 percent of the reduced amount of Chippewa River sediment supply attributable to implementation of this plan. A 90-percent efficiency was assumed. The effect on dredging after implementing the plan would not be immediate but would propagate downstream at a rate of about 1 mile per year. This alternative, considering the 117,000-cubic yard sediment trap, would reduce the dredging requirement about 110,000 cubic yards per year, compared to without-project conditions, by 2040. The effect of this alternative would be limited to river mile 757.0.

If the size of the sediment trap were doubled to 233,000 cubic yards per year, most of the dredging required in pool 4 would be eliminated, assuming the riverbanks and islands in pool 4 remain stable. Compared to the without project conditions, dredging requirements would be reduced about 150,000 cubic yards per year in pool 4 (as shown in the following table) and about 20,000 cubic yards per year in pool 5. Because of the reduction in sediment supply from the Chippewa River, stability of riverbanks in pool 4 downstream of the Chippewa River mouth could be affected and then could require protection. Considering the efficiency of the dredged trap and river stability, the sediment trap should not be larger than 150,000 cubic yards per year, which would reduce the dredging requirement in pool 4 by about 130,000 cubic yards per year mainly at the problem sites at Reads Landing, above Hershey Islands, and above Teepeeota Point.

Estimated dredging requirements in pool 4[1]

Sediment control plan	1992 With plan	1992 Compared to without project	2000 With plan	2000 Compared to without project	2010 With plan	2010 Compared to without project	2020 With plan	2020 Compared to without project	2030 With plan	2030 Compared to without project	2040 With plan	2040 Compared to without project
	Amount dredged (in 1,000 cubic yards per year)											
<u>Without project condition</u>	186[2]		180[2]		173[2]		168[2]		164[2]		161[2]	
<u>Plan 1</u>: Protect eroding Chippewa River banks and dredge a sediment trap on the lower Chippewa River												
Case 1: Dredge a sediment trap of 117,000 cubic yards per year	131	-55	80	-100	63	-110	58	-110	54	-110	51	-110
Case 2: Dredge a sediment trap of 233,000 cubic yards per year	128	-58	27	-153	18	-155	16	-152	15	-159	13	-148
<u>Plan 2</u>: Protect eroding Chippewa River banks and construct a low-head dam near the mouth of the Chippewa River												
Case 1: Construct a 6-foot low-head dam	131	-55	95	-85	108	-65	113	-55	113	-51	113	-48
Case 2: Construct a 10-foot low-head dam	131	-55	60	-120	74	-99	85	-83	90	-74	93	-68
<u>Plan 3</u>:[3] Construct a low-head dam near the Chippewa River mouth and dredge behind the dam												
Case 1: Construct a 6-foot low-head dam	131	-55	95	-85	88	-85	83	-85	79	-85	76	-85
Case 2: Construct a 10-foot low-head dam	131	-55	60	-120	53	-120	48	-120	44	-120	41	-120
<u>Plan 4</u>: Protect eroding Chippewa River banks, construct a low-head dam near the mouth of the Chippewa River and dredge behind the dam												
Case 1: Construct a 6-foot low-head dam	131	-55	95	-85	88	-85	83	-85	79	-35	76	-85
Case 2: Construct a 10-foot low-head dam	131	-55	60	-120	53	-120	48	-120	44	-120	41	-120
<u>Plan 5</u>: Employ a nonstructural alternative												
Case 1: Dredge a sediment trap of 117,000 cubic yards per year	131	-55	80	-100	73	-100	68	-100	64	-100	61	-100
Case 2: Increase the drawdown of six existing flood control dams in the Chippewa River basin												
a. Increase the drawdown by 3 feet for 1 month each year	158	-28	152	-28	145	-28	140	-28	136	-28	133	-28
b. Increase the drawdown by 5 feet for 1 month each year	143	-43	120	-60	113	-60	108	-60	104	-60	101	-60

(1) Table is compilation of tables 2.33, 3.6, 3.7, 3.12, 3.13, 3.15, 3.16, 3.18, 3.19, 3.20, - in "Investigation of Effects in Chippewa River Erosion and Silt Reduction Measures, Phase II B," by Colorado State University, August 1980.
(2) Without project dredging requirement.
(3) Plan 2 has same dredging reductions as plan 3.

Sedimentation rates in the backwater areas of pool 4 would not be significantly affected by the reduction of inflowing sediment from the Chippewa River except near channel off-takes. The reason is that the sediment deposited in backwaters consists of fine particles which are transported into the lower end of pool 4 mainly through Lake Pepin. Analyses of bed material samples indicate that about 95 percent of the Chippewa River sediment is larger than 0.2 millimeter, whereas the size distribution near the mouth of Robinson Lake shows that 50 percent of bed material is larger than 0.2 millimeter. This distribution indicates that some Chippewa River sediment reaches Robinson Lake and is deposited near its mouth. Considering the Mississippi River's own sources of sediment, the Chippewa River should contribute no more than two-thirds of this 50 percent, or 35 percent of deposition near the mouth of Robinson Lake. Away from the mouth in Robinson Lake, the sediment size decreases rapidly. Most of this sediment is carried into the area by the Mississippi River flow, possibly through Lake Pepin. Hence, the reduction of the Chippewa River sediment should not significantly affect this area (less than 5 percent).

The other large backwater area in lower pool 4, Big Lake, is located quite a distance from the main channel. There is less chance of the Chippewa River sediment reaching this lake than Robinson Lake. However, currently no data are available to determine the deposition rate contributed by Chippewa River sediment.

Sediment deposition near the mouth of backwater areas in the existing river system would total about 0.3 foot in 10 years. A 40-percent reduction in Chippewa River sediment would reduce sedimentation by 14 percent, or 0.005 inch per year. The effect of Chippewa River sediment is even less tangible in the more remote backwaters.

Ultimately, the reduction in the Chippewa River sediment supply would affect pools 5 and 5A. However, because the sediment discharge at lock and dam 4 is only about 55 percent of the sediment discharge supplied by the Chippewa River, this reduction would not significantly reduce dredging requirements in pools 5 and 5A unless the reduction was more than 50 percent of the original Chippewa River sediment supply rate and continued for more than 10 years. A conservative estimate is that, if the reduction in sediment

plied from the Chippewa River was more than 50 percent of the original sedi- t supply rate and if the riverbanks and islands in pool 4 remained stable, the ect on pools 5 and 5A would be no more than one-half of that portion more n 50 percent of the original supply rate.

Effects of this plan on the water surface hydrology would be minor ause, in most locations, the cross-sectional areas and resistance flow would not be significantly affected. Within the dredge cut, the ocity distribution would be affected locally. The dredge cuts would reduce average velocities.

2. Establish Streambank Erosion Controls and Construct a Low-Head at the Lower End of the Chippewa River

Implementation of streambank erosion controls aided by construction of a -head dam at the lower end of the Chippewa River appears to be a good ernative to reduce the sediment supply from the Chippewa River to the sissippi River and protect the Chippewa River floodplain from excessive s to the river. The erosion control structures, if shown effective by demonstration project, will be used in this alternative to protect banks. cost of using these structures to protect the nine major erosion sites ld be $0.5 million to $1 million. However, costs could be substantially her if more conventional erosion protection were required.

Riprap or crushed rock at least 8 inches in size could be used to con- uct the low-head dam. Two dams 6 feet and 10 feet high were evaluated. construction costs for the 10-foot dam which looks most promising in ucing sediment to the Mississippi River are estimated to range from ,000 to a conservative $722,000.

The geometric changes in the Chippewa River after implementation of this would be caused mainly by the streambank erosion controls except in the r Chippewa River below river mile 6. If the protective works were imple- ed at the nine major erosion sites and these measures effectively prevented banks from further erosion, the adjacent floodplain acreage saved from

erosion between 1990 and 2040 would total 30 acres. This is about a 25-percent reduction of the eroded floodplain area estimated for the without-project condition. Protection of these nine sites would reduce the sediment contributed by the bank erosion about 55 percent.

Compared to without project conditions, it was found that the overall erosion in the Chippewa River would be reduced by 50 percent by protecting banks and constructing a 10-foot low-head dam. Protection of eroding banks and construction of a low-head dam at the Chippewa River mouth would reduce the Chippewa River sediment supply to the Mississippi River. Because of sediment deposition upstream of the dam, the trapping efficiency of the dam would decline with time. Therefore, the reduction in the average Chippewa River sediment supply attributable to this alternative would decrease with time as shown in the table on page 34.

Because the dam's efficiency in trapping Chippewa River sediment would decrease with time, its effect on reduction in dredging requirements would decrease accordingly. The 6-foot dam plus bank protection would reduce dredging requirements between 48,000 and 85,000 cubic yards per year, compared to without project conditions. The 10-foot dam plus bank protection would reduce dredging requirements in pool 4 between 55,000 and 120,000 cubic yards per year. The effect of this plan would be limited to river mile 757.0, assuming the riverbanks along the lower end of the Chippewa River and the Upper Mississippi River were not changed by the reduction in the Chippewa River sediment supply.

The low-head dam would raise the flood stage above the normal flood (without the dam) immediately upstream. The 6-foot dam would raise the average flood stage (Q = 41,000 cfs) by about 1.3 feet; the 10-foot dam would raise it by about 2.0 feet. Passing of a 100-year flood (Q = 135,000 cfs) over the 10-foot dam would add about 3.0 feet to the normal 100-year flood stage near the dam.

Initially, the effects of these increases in flood stage on the Chippewa River floodplain would be limited to below river mile 6. Because of continuous sediment deposition upstream of the dam, the backwater effects would extend farther upstream with time.

The water surface elevation for an average flood (Q = 40,000 cfs) would submerge a large portion of the Chippewa River floodplain below river mile 1.5 and would reach about bank-full stage upstream of river mile 1.5. The stage rise caused by construction of the 10-foot dam would inundate about an additional 1,100 acres of floodplain, mainly between river miles 1.5 and 6. Most of this area is forest and marshland.

If the same flood occurred a few years after construction of the dam, a few hundred more acres would be inundated because of the further increase in stage caused by deposition of sediment upstream of the low-head dam. The duration of this inundation would be relatively short and should not significantly affect the forest land. At Q = 135,000 cfs (with a recurrence interval of about 100 years), the effect of the low-head dam on the floodplain would be less because the floodplain would be largely submerged under natural conditions.

3. Construct a Low-Head Dam at the Chippewa River Mouth and Dredge Behind the Dam

As described earlier, the effectiveness of a low-head dam in trapping sediment decreases with time if the deposited sediment is not removed. It is possible to dredge the sediment deposited behind the dam to maintain the effectiveness of the low-head dam. A 6-foot dam and a 10-foot dam with adequate dredging have been evaluated.

The geometric changes in the Chippewa River after implementation of this plan would be similar to without project conditions except in the river reach below river mile 6 where about 10 acres of floodplain land would be saved from erosion.

Dredging quantities required to maintain the trapping efficiency of the 6-foot dam would increase from 24,000 cubic yards in 2010 to 42,000 cubic yards in 2040. Maintenance dredging for the 10-foot dam would increase from 22,000 cubic yards in 2010 to 58,000 cubic yards in 2040. The quantities are slightly less than those of plan 3 because of the effects of bank protection.

Constructing a 6-foot dam at the Chippewa River mouth and performing maintenance dredging behind the dam could reduce the dredging requirement in pool 4 about 85,000 cubic yards per year. Constructing a 10-foot dam at the Chippewa River mouth and performing maintenance dredging behind the dam could reduce the dredging requirement in pool 4 about 120,000 cubic yards. The effect of this alternative would be limited to river mile 757.0 assuming the Mississippi River banks remain stable. The table on page 34 shows dredging reduction over the 50-year project life.

Impacts of this alternative on surface water hydrology would be similar to those caused by plans 2 and 3. Dredging the sediment deposited behind the dam would have some localized effect on the velocity distribution. It was found that the mean velocities in lower reaches of the Chippewa River would decrease with construction of a dam and dredging.

4. <u>Establish Stream Erosion Controls and Construct a Low-Head Dam at the Chippewa River Mouth with Dredging Behind the Dam.</u>

This alternative considers the protection of severely eroded banks and the construction of a low-head dam with dredging behind the dam to more effectively reduce the Chippewa River sediment supply entering the Mississippi River, similar to plan 3 above. The erosion control structures which prove effective in the Erosion Control Demonstration Project will be utilized to protect the nine major erosion sites. The cost for constructing these structures would be from $1/2 million to $1 million. Costs for constructing the dams would be the same as plans 2 and 3. Adequate dredging would be utilized to remove sediment deposited behind the dam.

5. Nonstructural Alternatives

Two nonstructural alternatives were evaluated: dredging a sediment trap at the lower end of the Chippewa River and increasing storage of existing dams in the Chippewa River basin to reduce downstream flood discharges.

a. Dredge a Sediment Trap at the Lower End of the Chippewa River. - Dredging a sediment trap at the Chippewa River mouth would cause only local geomorphic changes adjacent to the dredge cut. Therefore, the geometric changes in the lower Chippewa River would be similar to the without project conditions, except that the bed elevation changes in the lower reach of the river would be affected by dredging quantities.

The Chippewa River sediment supply into pool 4 would be reduced by about the weight of the material dredged from the sediment trap. The estimated sediment discharges would be about 4 percent higher in 2000, 6 percent higher in 2010, 8 percent higher in 2020, 9 percent higher in 2030, and 10 percent higher in 2040 than those of plan 1.

Dredging a trap of 117,000 cubic yards per year would reduce the dredging requirement in pool 4 by about 100,000 cubic yards per year by the year 2040 compared to without project conditions as shown in the table on page 14. The effect of this alternative would be limited to river mile 757.0. As discussed in plan 1, the size of the trap should not be larger than 150,000 cubic yards per year to avoid severely reducing the river stability. This would reduce the dredging requirement in pool 4 by about 120,000 cubic yards per year, mainly at the problem sites at Reads landing, above Hershey Islands, and above Teepeeota Point. Some reaches in the Chippewa River at and downstream of the dredge cut and in pool 4 within 6 miles downstream of the Chippewa River confluence could require bank protection.

The effects of this plan on the water surface hydrology in the lower Chippewa River would be very minor. Flow velocity would decrease locally within the dredge cut.

b. <u>Increase Storage of Existing Dams in the Chippewa River Basin.</u> - Numerous storage reservoirs and power generation dams have been constructed in the Chippewa River basin. These dams are generally drawn down in the fall to provide flood control the following spring. They can be operated to further reduce downstream flood discharges and thereby reduce Chippewa River erosion and the sediment supply to the Mississippi River.

A study of this plan shows that the discharge of sediment from the Chippewa River could be reduced by increasing the storage capacity of the six existing dams (Chippewa Dam, Holcombe Dam, Cornell Dam, Wissota Dam, Chippewa Falls Dam, and Dells Dam) by increasing the fall drawdown or by increasing the reservoir stages for flooding or both. The surface areas of Chippewa, Holcombe, Cornell, Wissota, Chippewa Falls, and Dells Reservoirs are about 15,000, 3,000, 600, 6,000, 110, and 600 acres, respectively. If the power pools of these reservoirs were lowered to provide an additional 5 feet for flood control storage, extra storage of 126,000 acre-feet would result. This extra storage would be sufficient to reduce the flood peak be properly operated. This increase in storage would lower the flood stage (Q = 46,000 cfs) in the Chippewa River about 0.9 foot and reduce the sediment supply to the Mississippi River about 15 percent (or about 90,000 tons per year). If these dams were modified to increase their storage capacity 50 percent of the above case, the flood stage in the Chippewa River would be lowered about 0.5 foot and the sediment supply to the Mississippi River would be reduced by 7 percent. This plan would immediately reduce the sediment supply in the Mississippi River.

The dredging requirement in pool 4 would be reduced after increasing reservoir storage. The estimated dredging quantities considering an additional 5-foot drawdown and a 3-foot drawdown to increase reservoir storage would be about 60,000 and 28,000 cubic yards per year, respectively, and are shown in the table on page 34.

The basin area of the Chippewa River affected by this alternative would be small. The economic benefits of this alternative should consider flood damage reduction and maintenance requirements resulting from the decrease in peak discharge and sediment supply from the Chippewa River. Conversely, power supply would be decreased, wild rice production would be reduced, some fish and wildlife resources would be lost, and other adverse impacts would be incurred.

Environmental Impacts. - The following discussion describes the predicted impacts of the plans on terrestrial and aquatic systems.

As far as can be determined by the limited amount of information available, the greatest impact from the sediment controls on the terrestrial systems would be on the wetlands, particularly those areas located at the Chippewa River's confluence with the Mississippi River. Generally, impacts on other terrestrial habitats would be minimal, except at those erosion sites where erosion control measures would be installed.

None of the proposed alternative erosion and silt control measures would have profound or permanent detrimental effects on the aquatic biota of the Chippewa River. Each plan would create some subtle changes affecting local benthic microinvertebrates or the zooplanktonic or phytoplanktonic populations in the stream. The shifts in populations would also be subtle, and the communities of organisms would adapt or, in some cases, give way to other species that find the altered environment more suitable. Overall, the survival and diversity of organisms should not be greatly affected. The subtle changes, however, cause locally modified habitats that could yield minor beneficial advantages for some of the plans. The construction of any plan could lessen the possibility for inclusion of portions of the Chippewa River in the National Wild and Scenic Rivers System. The introduction of man-made intrusions (i.e., intrusions from the proposed plans would have negative impacts on the river's high aesthetic values and increase the likelihood of noncompatibility of the project and potential for Wild and Scenic River designation (as outlined in Public Law 90-542)). The Chippewa River is one of the most highly regarded rivers in Wisconsin for inclusion in the National Wild and Scenic Rivers System.

If the project were completed, it is unclear whether the associated intrusions would eliminate those portions of the river in the project area from recreational or scenic qualification in the Wild and Scenic Rivers System.

Requirements for minimum length (25 miles) usually needed for designation could be adversely affected by the project. Project impacts may not be significant, considering the river was proposed for inclusion in the Wild and Scenic Rivers System even though the largest population center of the area (Durand) almost bisects the proposed length, leaving both segments below minimum length standards.

A more complete discussion of the biological impacts of the plans is found in "Investigation of the Effects of Chippewa River Erosion and Silt Reduction Measures, Phase II B" by Colorado State University, September 1980.

Socioeconomic Impacts. - A complete analysis of the impacts of each plan on the socioeconomic environment would require an assessment of the impacts of each plan on population levels, employment, and income over the 50-year planning period. "With project" levels would have to be compared with "without project" levels. A complete analysis of this nature could not be undertaken here because of the lack of sound estimates for future levels of population, employment, and income within the project area of the lower Chippewa River. It is believed, however, that the sediment controls will not generally have any effect on these variables. The effect on the socioeconomic environment should be minimal. Future levels of population, employment, and income within the project area will not be affected by the implementation of sediment control actions.

National Economic Development Plan. - This section describes the information used to analyze and evaluate the various sedimentation plans. Each plan was analyzed over a 50-year planning period. Benefits and costs for each plan were discounted at 7 1/8 percent. Although further studies may change the absolute amount of net benefits for each plan, the following analysis is thought to be adequate for screening purposes.

1. Dredging Requirements and Costs

The Mississippi River dredging requirements for each alternative were based on the dredging requirements for five cuts in pool 4. Figures for dredging quantities in pool 4 for each alternative were evaluated in "Investigation of the Effects of Chippewa River Erosion and Silt Reduction Measures, Phase II B" by Colorado State University, dated September 1980. This report also supplied Chippewa River dredging requirements for each plan.

An average cost per cubic yard of dredged material was computed for each of the five cuts in pool 4, based on 1985 to 2025 total costs and total dredging quantities for each cut. This information was supplied by the

Material and Equipment Needs Work Group of GREAT I. An average $4 per cubic yard dredging cost (hydraulic) was computed for the Chippewa River. Included in this cost is the cost of installing dredging equipment, site preparation expenses, and the cost of transporting dredged material to a placement site. Hypothetical installation, preparation, and transportation costs were supplied by Mini-Dredge, Inc., a private dredging firm in Grand Forks, North Dakota. These costs were based on a placement site near Pepin, Wisconsin, south of Highway 35 and north of the Burlington Northern Railroad line.

2. Initial and Annual Maintenance Costs

The plans were divided into structural and nonstructural components, with bank stabilization and the low-head dam being structural measures, and the sediment trap and the reservoir drawdown being nonstructural measures. Initial costs and annual maintenance costs for each measure were calculated as described below.

a. Initial Costs - Structural Measures. - Total costs for Chippewa River bank stabilization measures are estimated to range between $0.5 and $1 million. An average value of $750,000 was used to measure initial bank stabilization costs. The initial costs for the low-head dams were provided in the Phase IIB report: $21,000 for the 6-foot dam and $60,000 for the 10-foot dam. These initial costs may be low and more conservative estimates might be $550,000 and $722,000, respectively. The placement site for dredged material would have to be purchased in year 1990. Given a 7 1/8-percent discount rate, the present value of land costs is about $35,000.

b. Initial Costs - Nonstructural Measures. - The initial costs for establishing a sediment trap on the Chippewa River are estimated at $700,000 for the 233,000 cubic yard sediment trap and one-half that for the 117,000-cubic yard trap. An initial cost of $0 was also used for increasing reservoir drawdown because this measure involves no initial construction expenses.

c. Maintenance Costs - Structural Measures. - An average annual maintenance cost of $30,000 was computed for bank stabilization measures. This figure was based on a previous study assumption that the lower Chippewa River could flood every 5 years. Flooding would result in damages to bank stabilization devices. Total damages are estimated to range between 10

and 20 percent of original costs. An annual maintenance cost of $0 was used for the low-head dam. However, dredging behind the dam would be necessary to maintain its efficiency. The $4 per cubic yard dredging cost was applied to the quantity of material dredged to compute the annual maintenance cost in this case. Although technically this cost is for maintenance, this factor is accommodated above in the dredging requirements sections.

d. Annual Maintenance Costs - Nonstructural Measures. - The annual cost of reservoir drawdown was based on the yearly loss in hydroelectric power output as a result of the drawdown. Increasing reservoir drawdown would involve a cost in terms of losses to fish habitat and recreation on the reservoirs behind the dams. However, cost data for these two losses were unavailable at the time of this writing and have not been included.

One final point must be made regarding cost data used. Several of the plans involve a cost in the form of lost acreages. For example, the low-head dam would inundate land behind the dam. Precise estimates of the amount of acreage lost and the cost per acre were unavailable at the time of this writing and have not been included.

e. Recreation. - Recreation user-days for 10-year periods between 1990 and 2040 were calculated using the project area's population as a percentage of the State's population and applying this percentage to State recreation user-days. The three major recreation activities in the area are canoeing, fishing, and hunting. Participation data for each of these activities were summed yielding total 1990 recreation user-days for the area of 289,000. A user-day growth rate of 0.009 was used, based on total recreation user-days between 1900 and 2040.

These recreation figures were held constant for each plan. The assumption that recreational values remained constant for both the with- and without-project cases was also adopted. However, each of the alternatives would involve some benefit or cost to recreational activity. The provision of river access sites or the stabilization of river flow would benefit recreation. Likewise, a reduction in river turbidity and a reduction in bank erosion would improve the

scenic quality of the area, thus benefiting recreation. Obstruction of river access or navigation and loss to reservoir surface area and wildlife habitat caused by reservoir drawdown could reduce recreation in the area. Likewise, the location of the dredged material placement site could reduce the scenic quality of the area, reducing the value of the recreational experience.

3. Discussion of the Results

The most economically desirable plan is the 10-foot low-head dam option of plan 3, the pool behind which would be periodically dredged to remove the trapped sediment. Its net present value is nearly one and one-half times that of the next most desirable candidate, the 10-foot low-head dam option of plan 4. Bank protection alone does not appear to be a viable option because of the substantial initial cost. Note that use of bank protection with the low-head dam would increase the benefits substantially because dredging behind the dam would not be needed until some time after the year 2000, but costs of bank protection outweigh benefits as can be shown by comparing plans 3 and 4 below. The following table presents the NED rankings of the alternatives considered.

Expected values of plans

	Plan		Net present value[1]	NED ranking
1	Sediment trap and	117,000 cubic yards	$5,392,000	5
	bank protection	233,000 cubic yards	-10,683,000	
2	Low-head dam and	6-foot	617,000 to 88,000[2]	3
	land protection	10-foot	1,365,000 to 703,000[2]	
3	Low-head dam with	6-foot	1,443,000 to 914,000[2]	1
	dredging behind dam	10-foot	2,286,000 to 1,624,000[2]	
4	Low-head dam and bank	6-foot	725,000 to 196,000[2]	2
	protection with	10-foot	1,582,000 to 920,000[2]	
	dredging behind dam			
5	Nonstructural			
	a. Sediment trap	117,000 cubic yards	-4,366,000	
	b. Increase storage	3-foot drawdown	202,000[3]	4
		5-foot drawdown	536,000[3]	

(1) Present worth of the sum of the series of costs and benefits associated with each plan based on 7 1/8 percent discount factor and 50-year life.

(2) Lesser value considers most conservative cost estimated developed by Corps of Engineers. Other values consider cost estimates developed for the dams by California State University in "Investigation of Effects of Chippewa River Erosion and Silt Reduction Measures, Phase IIB" dated September 1980.

(3) Does not include reduced recreation and real estate value losses associated with reservoir drawdown.

It is safe to say that plan 1 at any scale of development is inferior to the other four; plans 2, 3, and 4 have the highest net benefits especially if one considers the unquantified disbenefits associated with plan 5 (the reservoir modifications).

Environmental Quality Framework Plan. - This plan emphasizes the quality of the environmental through the preservation or enhancement of important natural and cultural resources and ecological systems, while minimizing adverse effects on the environmental quality of the lower Chippewa River. The alternatives analyzed were formulated principally for erosion and silt reduction. In addition to effectively controlling erosion and sediment, these alternatives should preserve the quality of biological and cultural resources. Therefore, the plans were evaluated in light of enhanced environmental quality, leading to the development of an environmental quality plan.

In the analysis of the proposed control plans, various environmental quality criteria were used. They included the following:

1. Potential impacts on rare and endangered species.
2. Minimal impacts on fish and wildlife habitat.
3. Minimal impacts on cultural resources.
4. Minimization of impacts on wild and scenic rivers.
5. Elimination of erosion.
6. Retention of water quality.
7. Minimal impacts on recreation or open space areas.
8. Habitat enhancement.

The objective of the evaluation was to select that plan which most nearly satisfied all of these criteria.

Analyzing the table on page 46, the question of cost effectiveness of including bank protection arises. As three of the proposed alternatives include bank protection, it is appropriate that the question be addressed here, particularly in terms of its effect on environmental quality.

A number of high and low banks along the Chippewa River have been listed as major erosion sites. Stabilization of these sites would aid in controlling some of the sediment that would otherwise end up in the Chippewa River. The control of these sediments would aid in improving the terrestrial and aquatic habitats downstream, but the improvement in habitat is not a measure of their cost-effectiveness.

The Soil Conservation Service implemented a critical area treatment project along Elk Creek, a tributary of the Chippewa River. In general, it was felt that in this particular case the bank protection was not cost effective. Problems centered around deriving a value for the habitat and land being lost to erosion. Such values could then be compared with the costs of implementing control measures. The consensus appeared to be that the control measures were not cost-effective; the land being lost to erosion was not valuable enough to warrant the expense of bank protection.

Discussion with Fish and Wildlife personnel yielded a different conclusion. Bank stabilization would: (1) lead to a reduction in sediment enhancing downstream habitat by protecting the backwaters, (2) preserve the immediate terrestrial habitat by stabilizing eroding banks, and (3) lead to shoreline fish habitat enhancement.

It is extremely difficult to quantify habitat values in such a way as to become meaningful when making comparisons with the costs of bank protection. Particularly in the case of the Chippewa River, where erosion of upstream banks becomes a problem in downstream backwater sloughs and wetlands, no one seems to know for sure just how many acres are being affected, how much habitat is being lost to sedimentation. What is known for sure is that the sediment is a problem and it appears that the bank protection would offer some control of that problem. The potential of bank protection along the Chippewa River then would be that the immediate habitat would be protected while controlling or stopping the sediment that would otherwise be moving into downstream habitats. It is difficult

to determine at this early stage whether bank protection would be cost effective. More documentation is required describing the sedimentation occurring in the backwaters of the Lower Chippewa. Perhaps in this case it would be more to the point to devise other means of measuring cost effectiveness that include a closer evaluation of potential habitat loss.

To make the issue more complicated, the Chippewa River has been nominated for Wild and Scenic River status. Construction of erosion and sediment control measures could have possible negative impacts on the high aesthetic values of the river, thus increasing the likelihood of non-compatibility of the project and the potential for Wild and Scenic River designation (as outlined in Public Law 90-542). But here again, visual impacts would probably be minor and if the stream's biological systems are not going to be protected, then there is not much point in designating it as a wild and scenic river.

In summary, it is felt that in terms of environmental quality, bank protection should be adopted for the following reasons:

1. There would be a reduction in erosion.
2. Bank stabilization would bring about a reduction in sediment reaching backwater areas along the Lower Chippewa River.
3. There would be stabilization of the immediate terrestrial habitat.
4. Bank protection would offer shoreline enhancement for fish habitat.

With the position that bank protection be adopted as part of the control measures in the overall analysis, some of the proposed alternatives were rejected outright. Only three alternatives remained: numbers 1, 2, and 4. From there it was a matter of examing the efficiency of the alternative in meeting other environmental quality objectives and criteria and also to measure the predicted active life of the structure.

Both the sediment trap and the low-head dam require maintenance dredging ı order to maintain an efficient sediment trapping capacity over time. reduction in this capacity would lead to a resumption in time of sediment ɜposition in backwaters at the mouth of the Chippewa River and along the ıssissippi River below the mouth. Because alternative 2 contained no ıintenance dredging, it was eliminated.

The maintenance dredging, however, brings with it a problem, that of lacement. An effort must be made to look for beneficial use sites where ıe material can be used for construction, land reclamation, or habitat ɜvelopment. The objective is to select a use plan that will have the ɜast negative environmental impact. In regard to the material that would ɜ dredged out of the lower Chippewa River, more work is required to deter-ine how the material can best be used.

The rest of the analysis concentrates on a comparison of the two re-aining plans, numbers 1 and 4. An evaluation of the merit of the two was ased on their effectiveness in controlling erosion and sediment with the east negative environmental impact.

1. Streambank Erosion Controls with a Sediment Trap with Dredging Plan 1)

Assuming that the long-run predictions hold, and the bank protection easures reduce the sediment supply to the Mississippi River by about 5 percent, a total of 30 floodplain acres would be saved from erosion. his is 30 acres of bottomland habitat. The sediment supply would be re-uced by 10 percent, which indicates a reduction in the amount of sediment hat would potentially reach downstream backwaters.

A sediment trap must be used in order to further reduce the Chippewa iver sediment load. Dredging a trap of 117,000 cubic yards/year would educe the dredging requirement by about 110,000 cubic yards/year, or 0 percent. A proposed doubling of the size of the trap would further

reduce the Chippewa River sediment supply by about 66 percent to 130,000 tons/year by 2040. But a large reduction in Chippewa River sediment supply to the Mississippi River would cause degradation in the Mississippi River downstream of the confluence. There would a reduction in dredging required in pool 4 and downstream pools, but the bed degradation could reduce riverbank stability adjacent to the Chippewa River confluence necessitating bank protection. This bank instability could lead to further problems in the Nelson-Trevino bottoms.

To make a sediment trap effective in the long run, maintenance dredging is required. The problems associated with a placement site need to be addressed as indicated above, because the deposited material often has serious negative impacts on the surrounding environment.

2. Streambank Erosion Controls with a Low-Head Dam with Dredging Behind the Dam (Plan 4)

This plan would protect severely eroding streambanks along the Chippewa River, thereby protecting bottomland habitat, while also reducing the amount of sediment reaching the Mississippi River and presumably wetland and backwater areas. Two dam sizes were evaluated: a 6-foot dam and a 10-foot dam.

Conjunctively using the bank protection and the low-head dam would serve to control the sediments that up to now have been seeping into bottomland habitats. The 10-foot dam was found to be more effective in this control than the 6-foot dam. Use of bank protection and a 10-foot low-head dam would reduce overall erosion in the Chippewa River by 50 percent. Dredging requirements in pool 4 would be reduced by about 120,000 cubic yards.

Sediment deposition upstream of the dam would reduce the dam's trapping efficiency with time. This would lead to a decrease in the reduction of the Chippewa sediment supply. In order to maintain the trapping efficiency of the dam, dredging would be required. This leads to the same potential placement site problems discussed earlier.

There is also some question whether the low-head dam would interfere with fish migrating upstream. Two fish, the walleye and the shovelnose sturgeon, are known to migrate up the Chippewa River. The low-head dam, however, should not interfere with this migration.

A comparison of the two alternative measures found them to be very close in their effectiveness. By using reduction in dredging figures as a measure, the sediment trap would reduce dredging by 110,000 cubic yards; the low-head dam alternative by 120,000 yards. Based on the predicted erosion and sediment that could be expected from these measures, the 10-foot low-head dam alternative using bank protection was seen as being effective in terms of environmental quality. Actual field data do not exist that would permit more accurate predictions of the effect of these measures on the area systems - particularly in the wetlands at the Chippewa River mouth. The problem of the suitable placement site is a serious one and should be addressed in the final design plans of the selected control measure.

In summary, it was felt that the alternative control measure selected would: (1) preserve the floodplain environment by controlling the bank erosion, (2) improve the quality of wetland and backwater habitats for area fish and wildlife, and (3) safeguard floodplain areas where potential archeological and historic sites might be located. Measuring the actual environmental benefits that potentially could be derived from this alternative is at this point impossible without sound data. It is not possible to make other than qualitative predictions; however, from the above discussion of the plans evaluated, plans 1 and 4 appear to be the best candidates for an environmental quality plan.

3. <u>Candidate Combination Plan</u>

The objective of this plan is to describe an alternative control measure that meets both NED and EQ criteria. Results of the NED analysis showed that the most economically desirable alternative was the 10-foot low-head

dam with periodic maintenance dredging. Using bank protection measures as well would substantially increase the environmental benefits of the low-head dam.

The results of the NED analysis agree with the proposed EQ plan. In terms of meeting environmental quality and national economic objectives, bank protection along with the 10-foot low-head dam, with maintenance dredging, was considered best among the proposed alternatives.

4. Nonstructural Plan

Results of analyses performed in this study do not show that any nonstructural alternative proposed is feasible, particularly in meeting environmental and economic objectives. The two alternatives proposed were:

a. Dredging a sediment trap at the lower end of the Chippewa River.

b. Increasing storage of existing flood control dams in the Chippewa River basin.

Neither appeared feasible in reducing the erosion and sediment problem along the Lower Chippewa River while meeting EQ and NED objectives at the same time.

5. Concluding Remarks

The purpose of this section of the report has been to examine in detail all of the alternatives and to select that measure which would most efficiently and effectively control the erosion and sediment along the Lower Chippewa River while at the same time promoting national economic development and environmental quality. This analysis was performed on what is known thus far of the biological, socioeconomic, and cultural environments. Results of the overall analysis showed that:

a. A nonstructural measure did not appear feasible.

b. Bank protection increased the overall benefits of any structural measure.

c. The 10-foot low-head dam appeared to have greater potential environmental and economic benefits than other proposed structural measures, but only if used in conjunction with bank protection and if there was dredging behind the dam.

Candidate Combination Plan. - The objective of this plan is to describe an alternative control measure that meets NED and EQ criteria. Results of the NED analysis showed that the most economically desirable alternative was the 10-foot low-head dam with periodic maintenance dredging. Using bank protection measures as well would substantially increase the benefits (especially environmental) of the low-head dam.

In terms of meeting environmental quality and national economic objectives, bank protection along with the 10-foot low-head dam and with maintenance dredging was considered the best of the proposed alternatives.

Nonstructural Plan. - The results of analyses performed for this study do not show that any nonstructural alternative proposed is acceptable, particularly in meeting environmental and economic objectives. The two alternatives proposed were:

1. Dredging a sediment trap at the lower end of the Chippewa River.

2. Increasing storage of existing flood control dams in the Chippewa River basin.

Neither appeared feasible in reducing the erosion and sediment problem along the lower Chippewa River while meeting the EQ and NED objectives.

Conclusions

The purpose of this report has been to examine all the alternatives in detail and select that plan that would most efficiently and effectively control erosion and sediment along the lower Chippewa River while promoting national economic development and environmental quality. This analysis was performed on what is known thus far of the biological, socioeconomic, and cultural environments. Results of the overall analysis showed that:

1. No nonstructural measure appeared feasible.

2. Bank protection would increase the overall benefits of any structural measure but would not be cost effective in itself, especially if traditional measures were used.

3. The 10-foot, low-head dam appeared to have greater potential environmental and economic benefits than other proposed structural measures, but only if used in conjunction with bank protection and with dredging behind the dam. This plan should be studied in detail in the Corps of Engineers Chippewa River basin feasibility report scheduled for completion in 1986.

It has become apparent that several areas require more intensive investigation. These areas should be part of the Corps final feasibility report and other studies:

1. Sediment transport should continue to be monitored at the three gaging stations: Pepin, Durand, and Caryville.

2. The demonstration project areas should also be monitored, not only in terms of sediment, but also to find out how these stabilization projects affect the fish populations and area recreation potential.

3. Serious concern has been voiced about the impacts of Chippewa River sediment on wetland areas at the river's junction with the Mississippi River. A thorough survey of the terrestrial and aquatic systems of this area should be done to determine the seriousness of the sediment problem. Only then can it be accurately determined how effective the proposed plans will be in improving the environmental quality of these wetlands.

4. For certain of the proposed control measures to be effective, maintenance dredging is required. An adequate material placement site needs to be found where potential secondary negative environmental impacts can be avoided. This placement site problem needs to be addressed in future analyses of this project.

5. More intensive recreation studies are needed for this area to predict more accurately the economic effects of the various control measures.

During stage 3, the impacts of the plans found most feasible so far will be further analyzed and compared to the without project condition. This information, together with the results of the demonstration program and the studies recommended above, will lead to recommendation of a plan to control erosion on the lower Chippewa River. This recommendation will be included in the feasibility report scheduled for submission to Congress in 1986.

CHAPTER V

CHANGE IN AQUATIC HABITAT, 1939-1973, POOLS 5 THROUGH 10

INTRODUCTION

The work that has been done with Cs-137 sediment dating, spud surveys, fathometer recordings, and the resurvey of Lake Pepin has established that sedimentation is occurring rapidly in the GREAT I reach of the Mississippi River. The cartographic work presented in this chapter attempts to describe where this sediment is being deposited and the relative amount of aquatic habitat being lost to sedimentation.

STUDY DESCRIPTION

The University of Minnesota interpreted the types of vegetation present on a series of preimpoundment (1939) aerial photographs of pools 5 through 10. The same process was performed on a set of 1973 photos. By comparing the types of vegetation identified on each set of maps, the areas of open water in 1939 which have been converted (lost) to emergent aquatic habitat were delineated. In addition, areas which changed from emergent aquatic habitat in 1939 to open water in 1973 were also identified. Because emergent aquatic vegetation exists in permanently anaerobic sediments (Wetzel, 1975), the areas which changed from open water to emergent aquatics were determined to be the locations of fine sediment deposition. Locations that show shifts from emergent plants to open water are assumed to be erosion or scour areas.

Despite efforts to minimize variations, location inaccuracies, pool elevations, and time of year discrepancies during photographing caused some error. However, the data presented by this technique clearly demonstrate the habitat changes that have occurred.

CARTOGRAPHIC REVIEW

To illustrate the extent of habitat conversion, the SEWG (through the Soil Conservation Service) prepared a set of 22 maps (pools 5 through 10) and an index sheet which depict the three changes that have taken place:

1. Loss of open water areas to fine sediment deposition.

2. Loss of open water areas to dredged material disposal.

3. Increase in open water areas caused by erosion.

Several variables must be noted when reviewing these maps:

1. The large areas of open water aquatic habitat which have been converted to emergent aquatic vegetation as a result of fine sediment deposition.

2. The location of habitat lost within the ri er corridor.

3. Comparison of areas lost to fine sedimentation and disposal of dredged material.

4. Effects and location of contributing tributaries and the associated loss of habitat to sedimentation.

5. Effects of in-channel flow and water level control devices including locks and dams and particularly dikes in relation to the location of habitat loss areas.

RESULTS

The 22 maps clearly show that tremendous amounts of open water areas have been converted to emergent vegetation habitat since impoundment, reflecting rapid and widespread deposition of fine sediments. Loss of aquatic habitat as a result of dredged material placement is negligible when compared to areas affected by fine sedimentation. By comparison, then, the greatest extent of sedimentation-caused environmental degradation which is occurring in the river corridor is caused by fine sediment accumulation. Any remedial action should place highest emphasis on prevention of fine sediment deposition. Prevention of sediment production at the source is ultimately the only solution to this problem. Data gathered and determinations made in chapters 2 and 3 conceptually corroborate the information portrayed by the maps.

Pool-by-pool comparisons indicate that several pools appear to be aggrading and losing habitat faster than others. These variances can be explained in most cases by locating incoming tributaries and observing habitat changes downstream from their points of confluence with the Mississippi River.

Areas below tributaries which have lost extensive aquatic habitat indicate high fine sediment yield from those drainage areas (see Wamandee Creek - sheets 4, 5, and Upper Iowa River - sheets 15-16). If little habitat loss occurs below tributary confluence, relatively small amounts of fine sediment enter the Mississippi River from that drainage area (see Wisconsin River - map 20-21).

Because sediments remain in suspension as long as flow capacity supports them, areas exhibiting low flow are most prone to sedimentation of fines. Lower pool lakes, backwaters, and off-channel sloughs typically possess low-flow tendencies and are therefore the most susceptible to fine sedimentation.

As previously described in this report, abatement of fine sedimentation and its related environmental damage depends on prevention of erosion at the source - areas in agricultural use. However, in-channel measures can be used to eliminate or reduce the environmental impacts of fine sedimentation. Dike construction at critical habitats would prevent fine sediment from entering the isolated area and therefore prevent fine sedimentation. GREAT's Fish and Wildlife Work Group (FWWG) has examined the potential of dike construction with flow regulating devices such as closing dams and gated culverts to rehabilitate declining backwater habitat. While such diking may be feasible for restoring environmental value, careful engineering analysis must be made on a site-by-site basis so that other problems, particularly flood elevation increases and winterkills of fish, are avoided.

The Corps of Engineers ongoing shoreline protection program can prevent habitat loss or decline from fine sedimentation. Under this program, rock riprap is placed at main channel border areas to prevent bank erosion and secondary movement of dredged material caused primarily by towboat prop wash and seasonal flood flows. When riprap is placed on both banks of side channel openings, water flow constriction prevents coarse sediments from depositing, and, therefore, freshwater supply to backwater areas is maintained. Shoaling at these openings is more likely to occur if they are unprotected. If closure results, backwater areas are deprived of consistent flow and are prone to aggradation of fine sediments. The SEWG and two other GREAT work groups (the Fish and Wildlife and Dredging Requirements Work Groups) have prepared a list of areas which should be protected by riprap under the shoreline protection program. Protection at these areas will help prevent further decline of backwater areas by fine sedimentation.

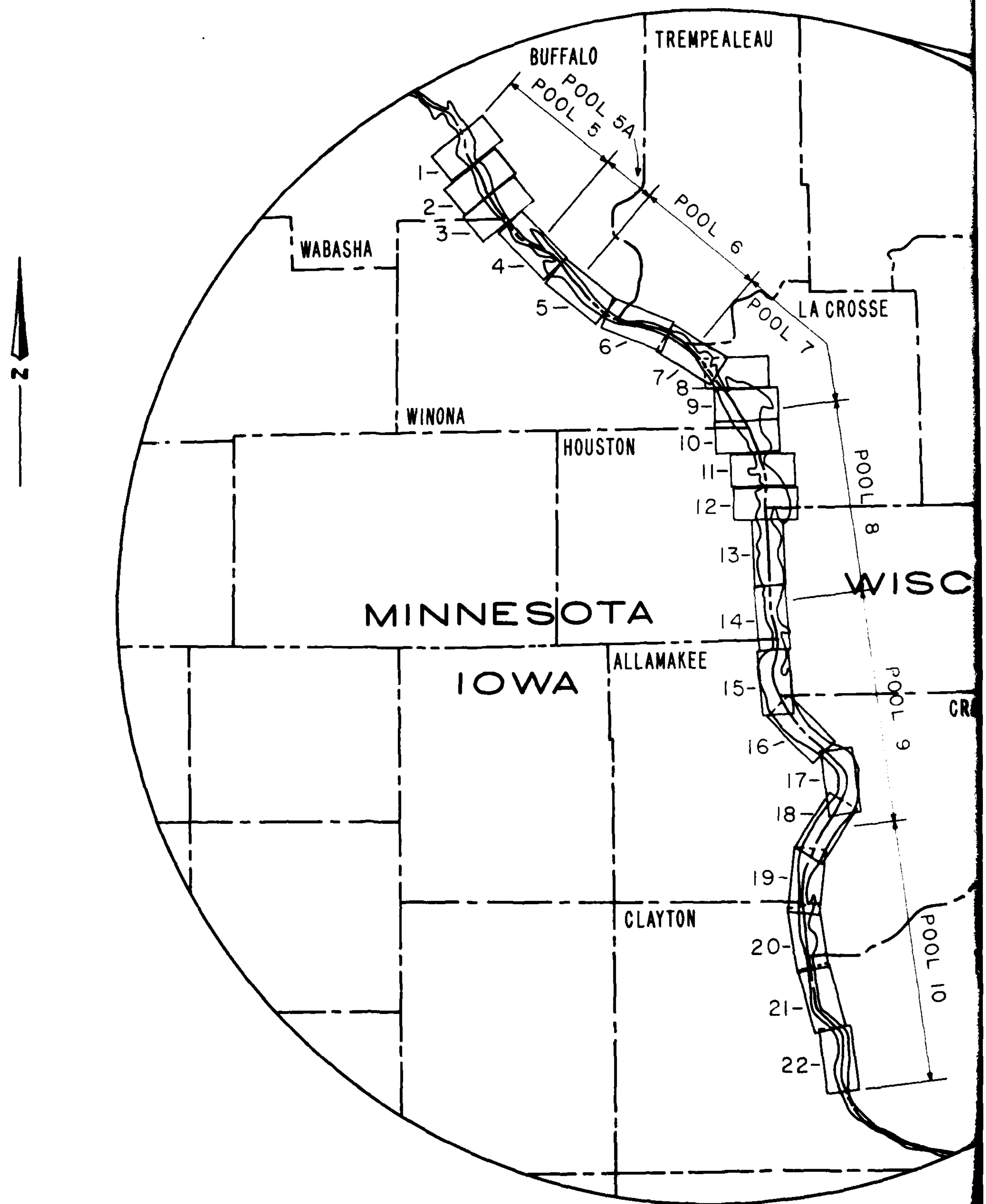
CONCLUSIONS

The change in aquatic habitat maps illustrate that a tremendous amount of open water area has been converted to emergent aquatic vegetation over the last 34 years, indicating widespread accumulation

of fine sediments in pools 5 through 10. The fine sedimentation causing habitat degradation encompasses significantly more area than does dredged material placement.

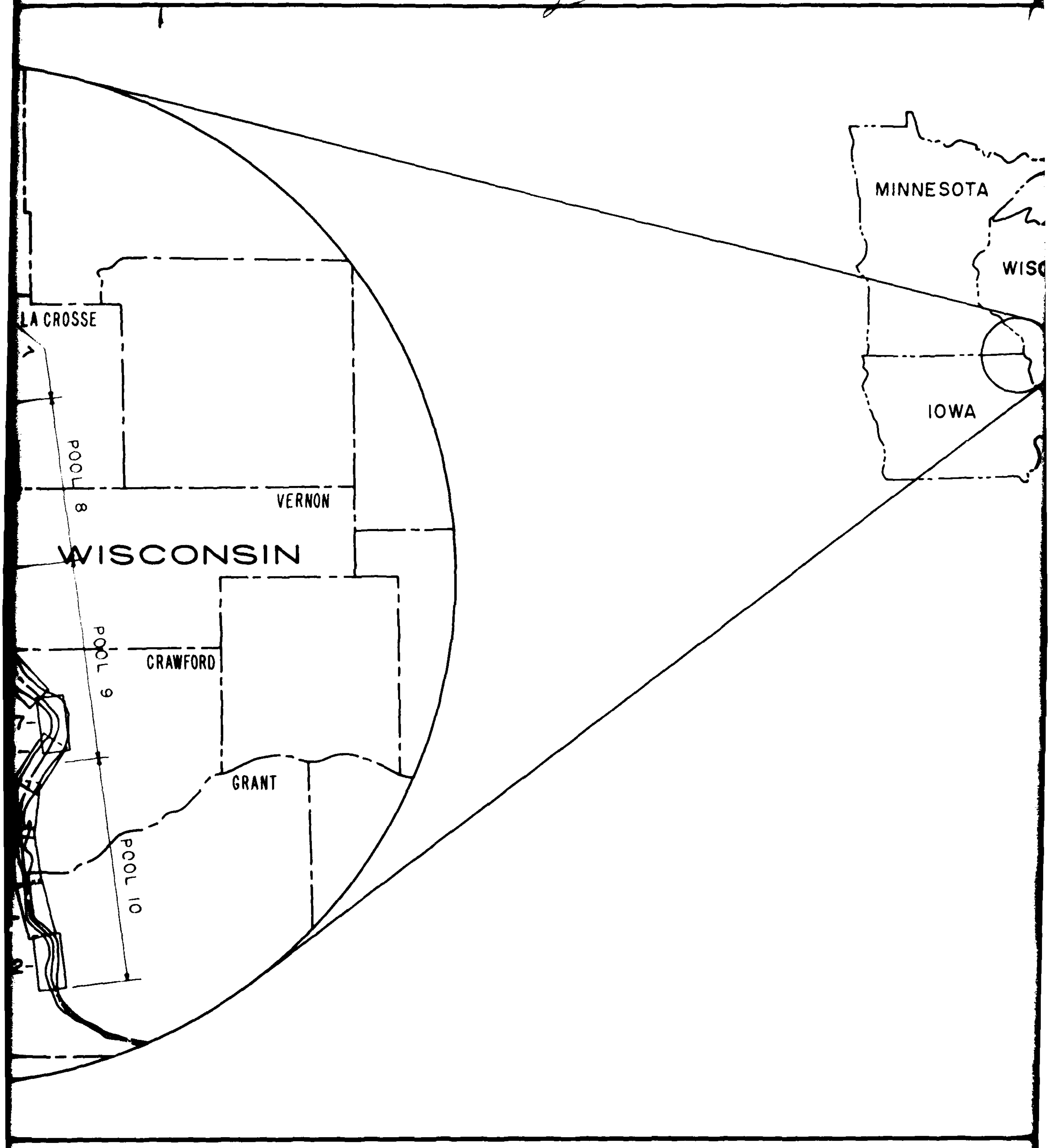
As corroborated by the sedimentation rates, widespread fine sedimentation will only be remedied by controlling erosion of upland areas under agricultural use. In-channel sediment abatement measures, including diking and shoreline protection, can be used at strategic locations to help prevent further decline of habitat by preventing fine sediments from accumulating.

U. S. DEPARTMENT OF AGRICULTURE

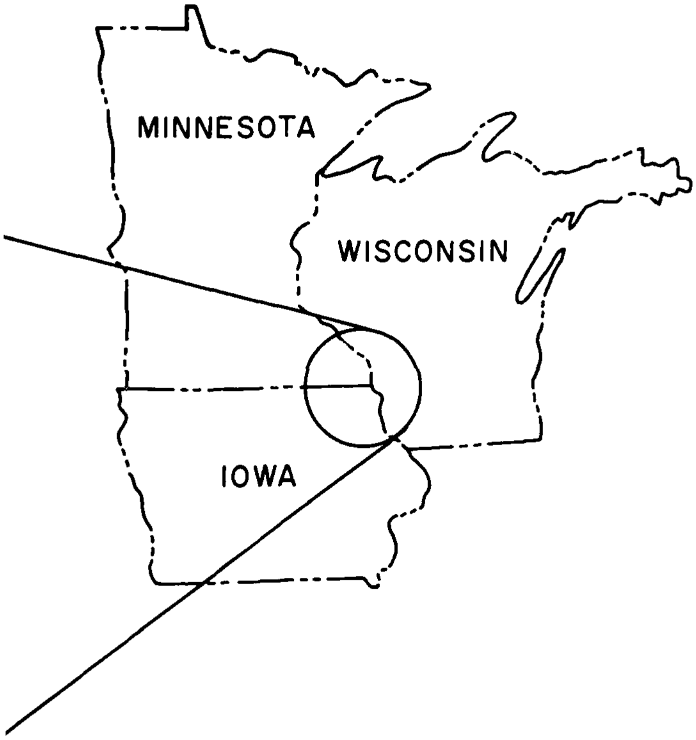


SOURCE:
BASE DERIVED FROM SCS DRWG. 5,S-21,812
PROJECTION UNKNOWN

USDA-SCS-LINCOLN, NEBR. 1978



MINNESOTA
WISC
IOWA
LA CROSSE
POOL 8
VERNON
WISCONSIN
POOL 9
CRAWFORD
GRANT
POOL 10



LEGEND

SHEET LOCATION

SHEET INDEX MAP FOR CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA AND WISCONSIN

7-13-78
5,P-36,886

LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION

LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL

INCREASE IN W... ... AREA DUE TO EROSION

THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA.

SCALE 0 2000 4000 6000 FEET

0 500 1000 1500 METERS

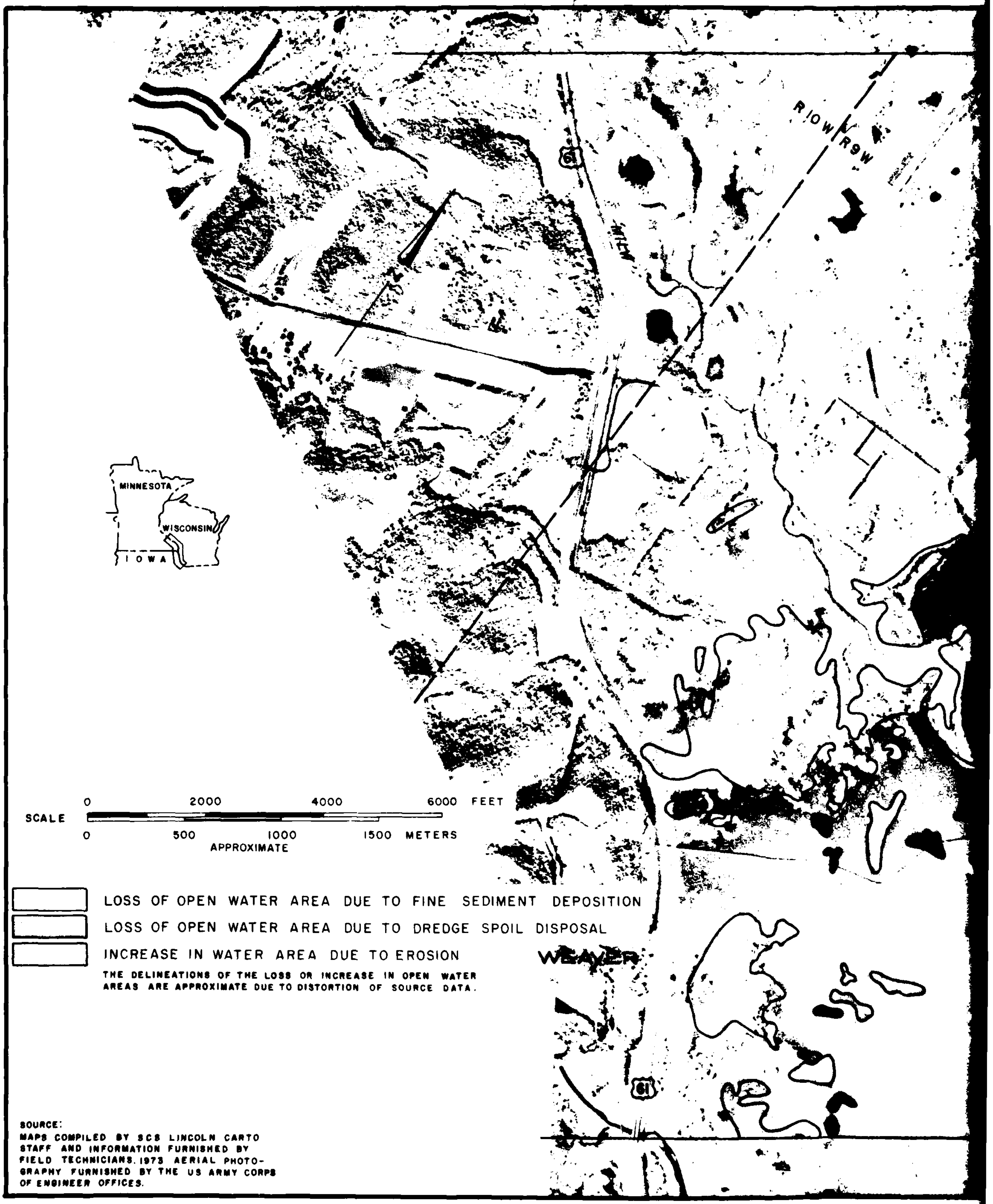
APPROXIMATE

...JRCE:
...PS COMPILED BY SCS LINCOLN CARTO
...AFF AND INFORMATION FURNISHED BY
...LD TECHNICIANS. 1973 AERIAL PHOTO-
...APHY FURNISHED BY THE US ARMY CORPS
... ENGINEER OFFICES.

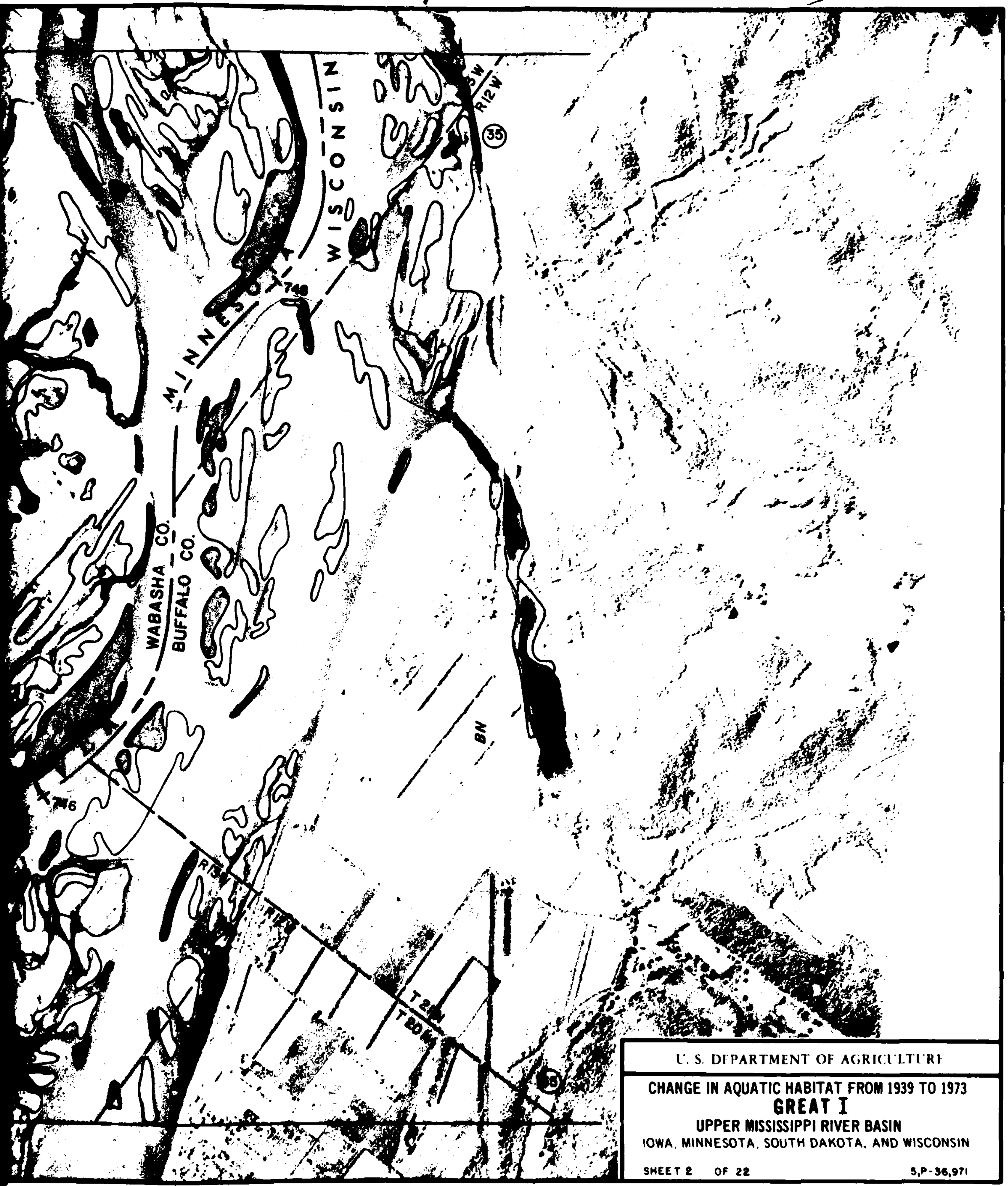
...DA-SCS-LINCOLN, NEBR. 1978

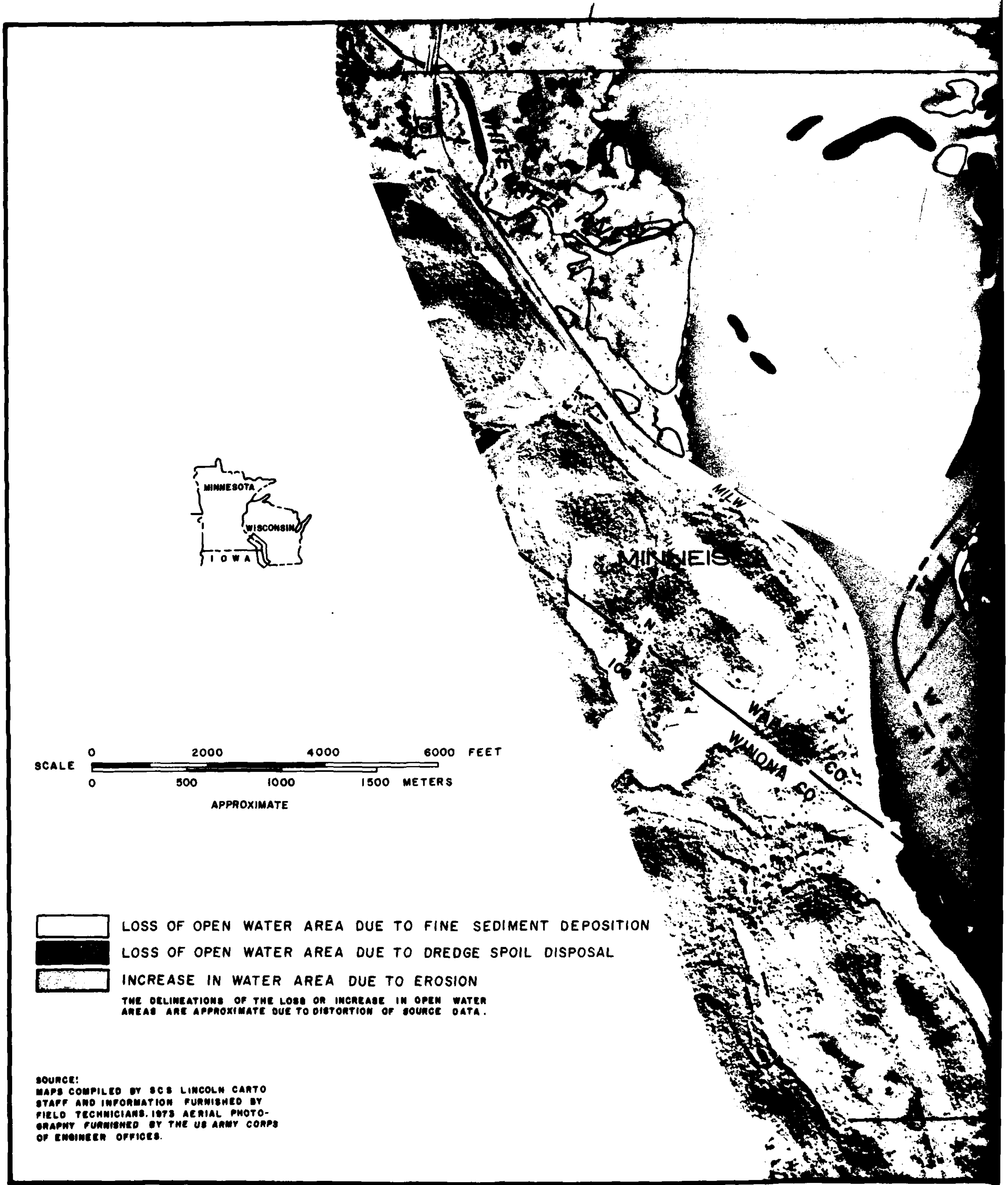
2
ZUMBRO RIVER
R10W
R9W
LOCK & DAM NO. 4
MINNESOTA
WISCONSIN
750
BUFFALO CO.
WABASHA CO.
35
JOINS SHEET 2

LOCK & DAM NO. 4
R10W
R9W
MISSISSIPPI RIVER
35
T 22 N
T 21 N
ALMA
752
MINNESOTA
WISCONSIN
BN
R 13 W
R 12 W
750
BUFFALO CO.
WABASHA CO.
35
U. S. DEPARTMENT OF AGRICULTURE
CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973
GREAT I
UPPER MISSISSIPPI RIVER BASIN
IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN
SHEET 1 OF 22
5,P-36,971

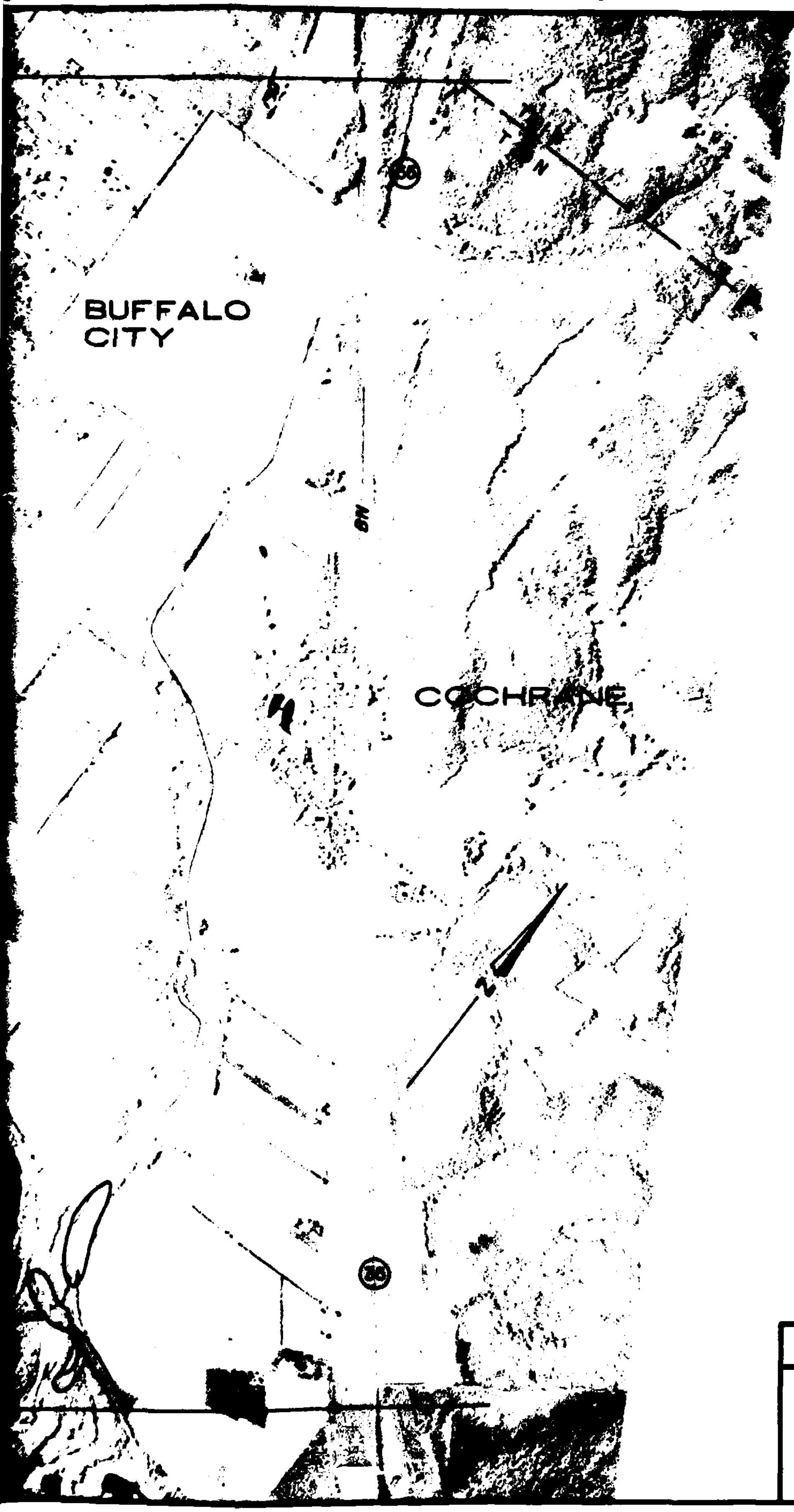

R10W
R9W
61
MILW
MINNESOTA
WISCONSIN
IOWA
SCALE
0 2000 4000 6000 FEET
0 500 1000 1500 METERS
APPROXIMATE
LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION
LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL
INCREASE IN WATER AREA DUE TO EROSION
THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA.
WEAVER
61
SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.

JOINS SHEET 1
T 109 N
R9W
MINNESOTA
WISCONSIN
748
WABASHA CO.
BUFFALO CO.
MISSISSIPPI RIVER
746
R13W
R12W
JOINS SHEET 3


MINNESOTA
WISCONSIN
WABASHA CO.
BUFFALO CO.
R12W
35
748
BN
R13W
T 21 N
T 20 N
U. S. DEPARTMENT OF AGRICULTURE
CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973
GREAT I
UPPER MISSISSIPPI RIVER BASIN
IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN
SHEET 2 OF 22
5,P-36,971


MILW
WINONA CO.
MINNESOTA
WISCONSIN
IOWA
SCALE
0 2000 4000 6000 FEET
0 500 1000 1500 METERS
APPROXIMATE
LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION
LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL
INCREASE IN WATER AREA DUE TO EROSION
THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA.
SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.


JOINS SHEET 2
R12W
BUFFALO
CITY
744
MISSISSIPPI RIVER
COCHR
742
WISCONSIN
MINNESOTA
BUFFALO CO.
JOINS



U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 3 OF 22 5,P-36,971

SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES

[illegible] OPEN WATER AREA DUE TO FINE [illegible]

[illegible] OPEN WATER AREA [illegible] DREDG[illegible]

[illegible] IN WATER AREA [illegible] EROSION

THE DELINEATIONS [illegible] THE LOSS OR INCREASE IN OPEN WA[illegible] AREA ARE APPROXIMATE [illegible] DISTORTION OF [illegible] DA[illegible]

AREA DUE TO FINE SEDIMENT DEPOSITION

AREA DUE TO DREDGE SPOIL DISPOSAL

AREA DUE TO EROSION
S OR INCREASE IN OPEN WATER
TO DISTORTION OF SOURCE DATA

SCALE 200 400

APPROXIMATE

1 3

SCALE 0 2000 4000 6000 FEET

0 500 1000 1500 METERS

APPROXIMATE

U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA MINNESOTA SOUTH DAKOTA AND WISCONSIN

SHEET 4 OF 22 5.P 36,971

SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES

SCALE 0 2000 4000 6000 FEET
0 500 1000 1500 METERS
APPROXIMATE

LOSS OF OPEN WATER AREA DUE TO FINE [illegible]

LOSS OF OPEN WATER AREA DUE T[illegible] DREDGE [illegible]

INCREASE IN WATER AREA DUE [illegible] EROSION

THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA

EDIMENT DEPOSITION

SPOIL DISPOSAL

MINNESOTA
WISCONSIN
IOWA

U S DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA MINNESOTA SOUTH DAKOTA AND WISCO..IN

SHEET 5 OF 22 5,P-36,971


T 19N
T 18N
54
35
BUFFALO CO.
TREMPEALEAU CO.
SHEET
BN
724
WINONA
WISCONSIN
MINNESOTA
722
BUFFALO CO.
TRE
HOMER
T107N
T106N
14
61
SCAL

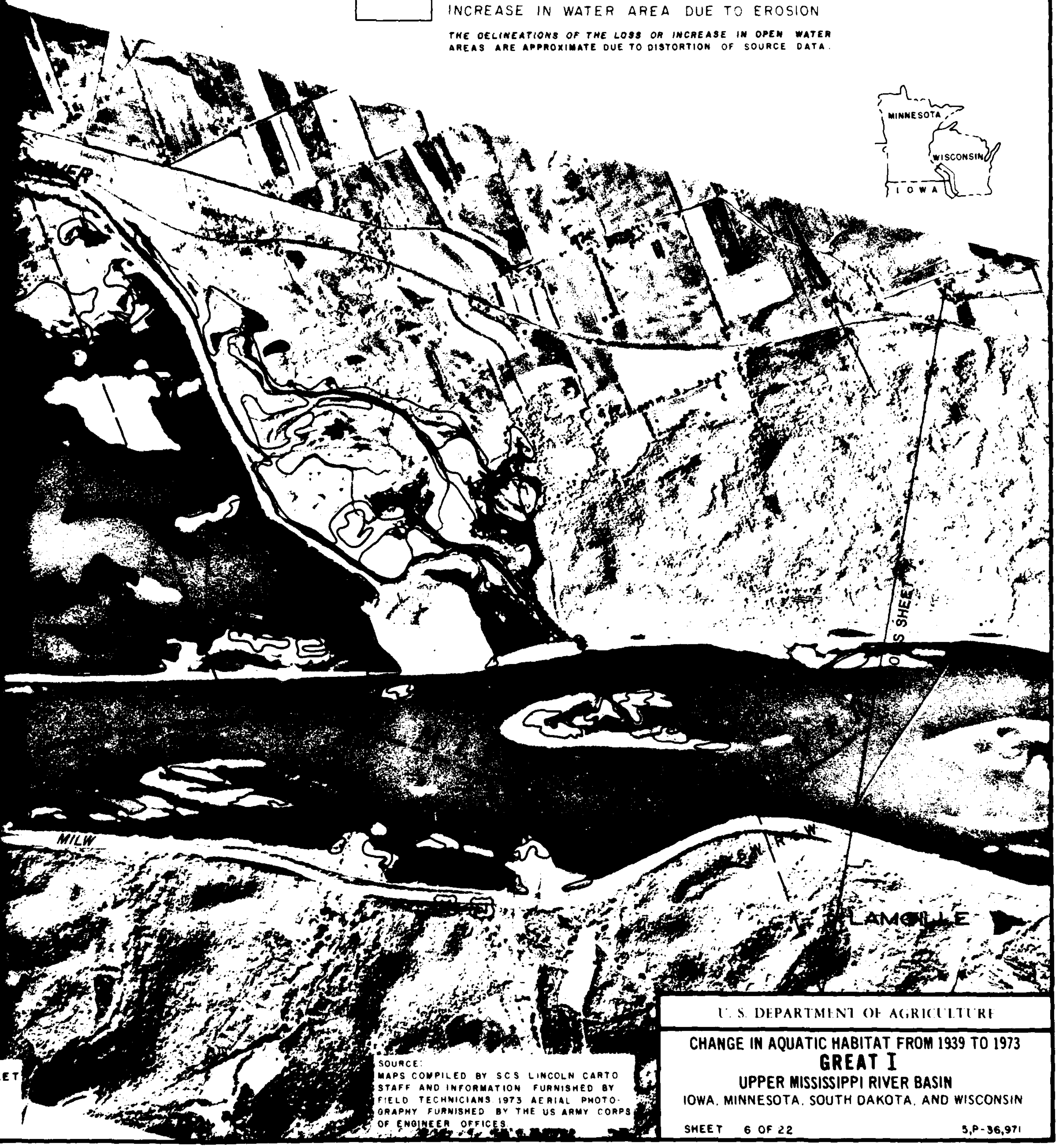
THE DELINEATIONS OF
AREAS ARE APPROXIMAT
R10W
TREMPEALEAU
RIVER
MIS
MILW
TREMPEALEAU
OMER
0 2000 4000 6000 FEET
SCALE
0 500 1000 1500 METERS
APPROXIMATE
SOURCE
MAPS COMPILED BY SCS LINCOL
STAFF AND INFORMATION FURNIS
FIELD TECHNICIANS 1973 AERIAL
GRAPHY FURNISHED BY THE US A
OF ENGINEER OFFICES

LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION

LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL

INCREASE IN WATER AREA DUE TO EROSION

THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA.



SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES

U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 6 OF 22 5,P-36,971


THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA
LOSS OF OPEN WATER AREA DUE TO
LOSS OF OPEN WATER AREA DUE TO
INCREASE IN WATER AREA DUE TO
MINNESOTA
WISCONSIN
IOWA
93
TREMPEALEAU
716
SHEET 6
LOCK & DAM NO.6
14
61
LAMOILLE
R6W
R5W
SOURCE
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES


ER AREA DUE TO FINE SEDIMENT DEPOSITION
ER AREA DUE TO DREDGE SPOIL DISPOSAL
AREA DUE TO EROSION
R9W
R8W
CNW
BN
T17N
TREMPEALEAU CO.
LA CROSSE CO.
MILW
SCALE
0
2000
4000
6000 FEET
0
500
1000
1500 METERS
APPROXIMATE

U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

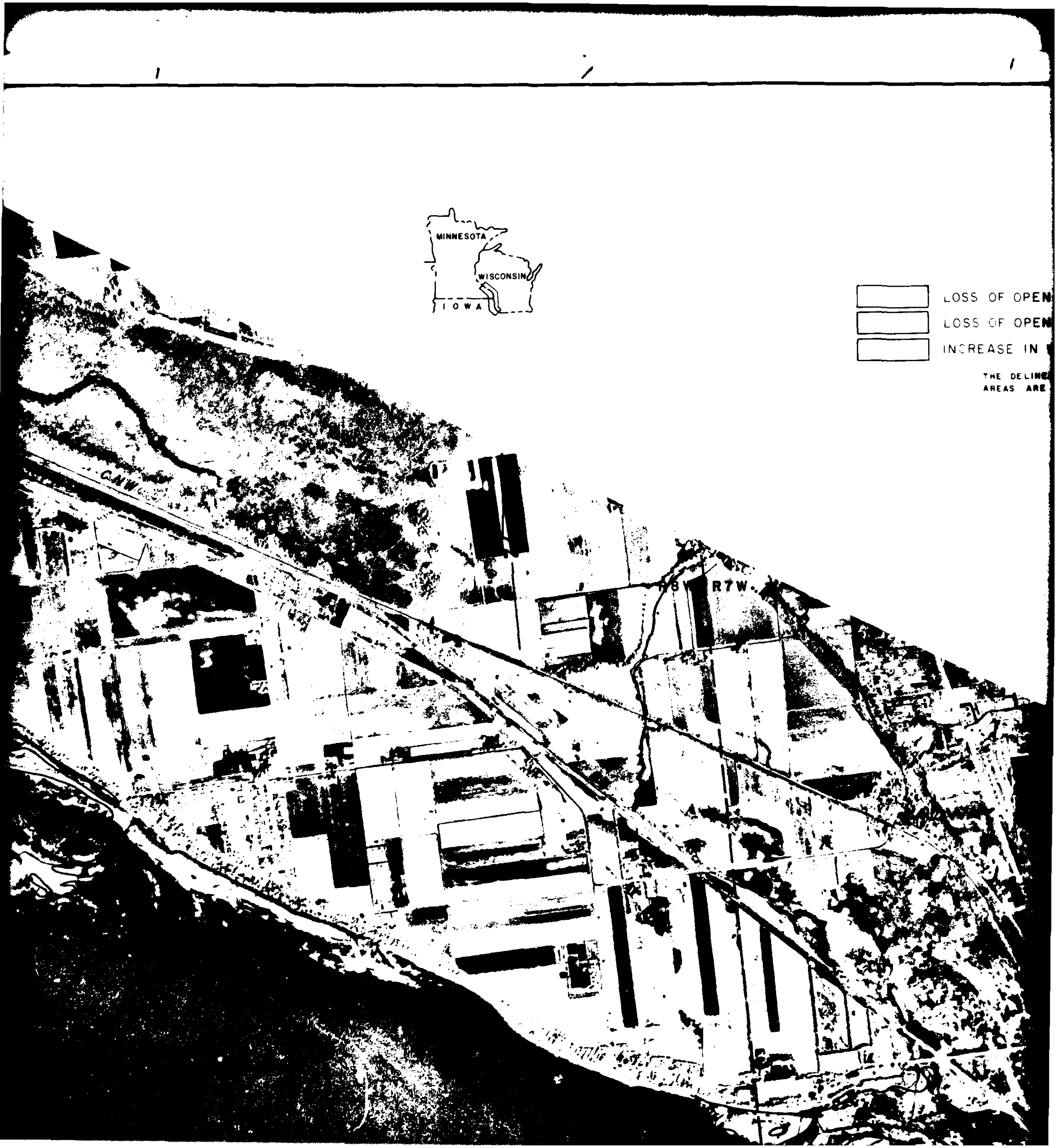
UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 7 OF 22

5,P-36,971

SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.



MINNESOTA
WISCONSIN
IOWA
LOSS OF OPEN
LOSS OF OPEN
INCREASE IN
THE DELINE
AREAS ARE
C.N.W.
R7W.

LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION

LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL

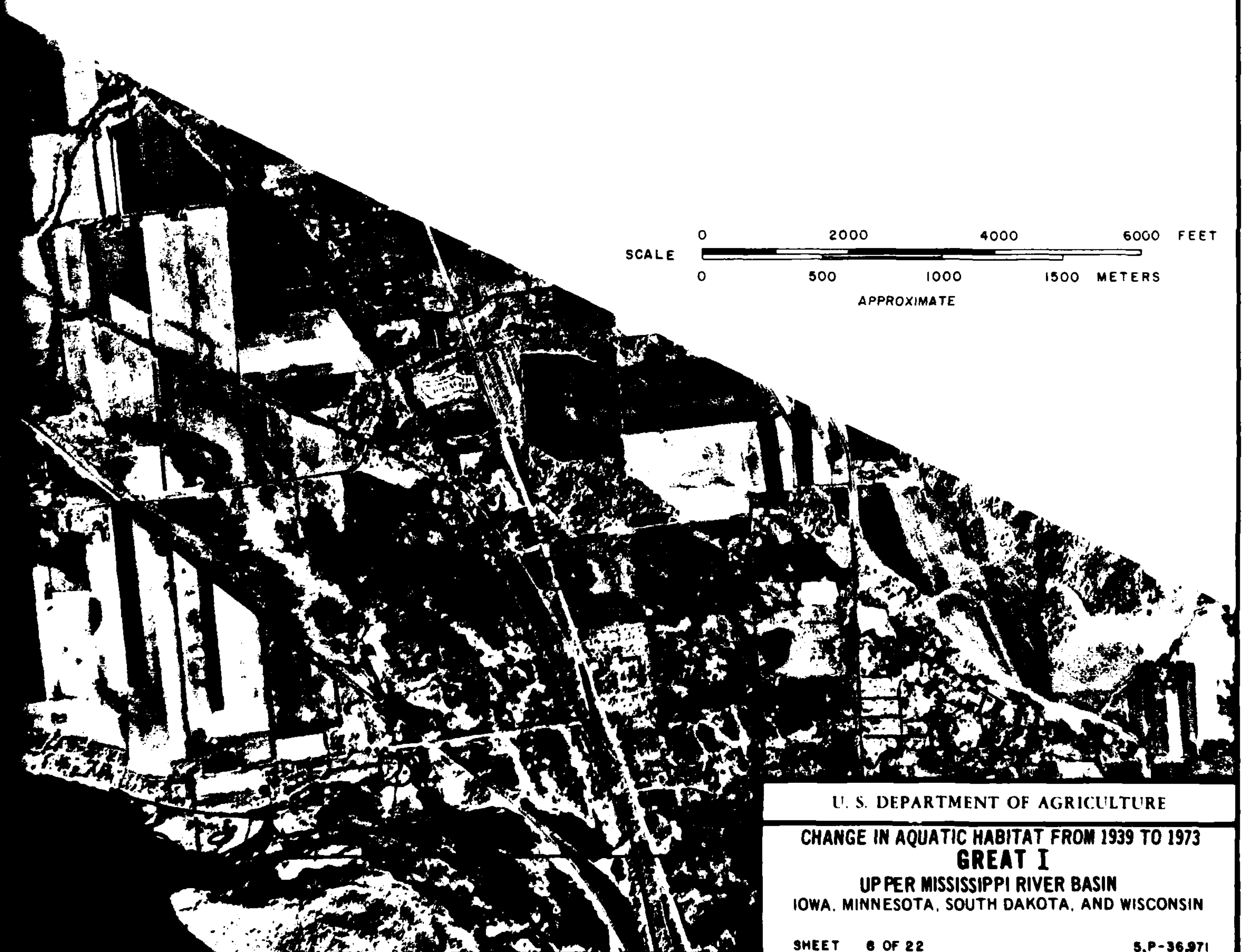
INCREASE IN WATER AREA DUE TO EROSION

THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA.

SCALE 0 2000 4000 6000 FEET

0 500 1000 1500 METERS

APPROXIMATE



U. S. DEPARTMENT OF AGRICULTURE

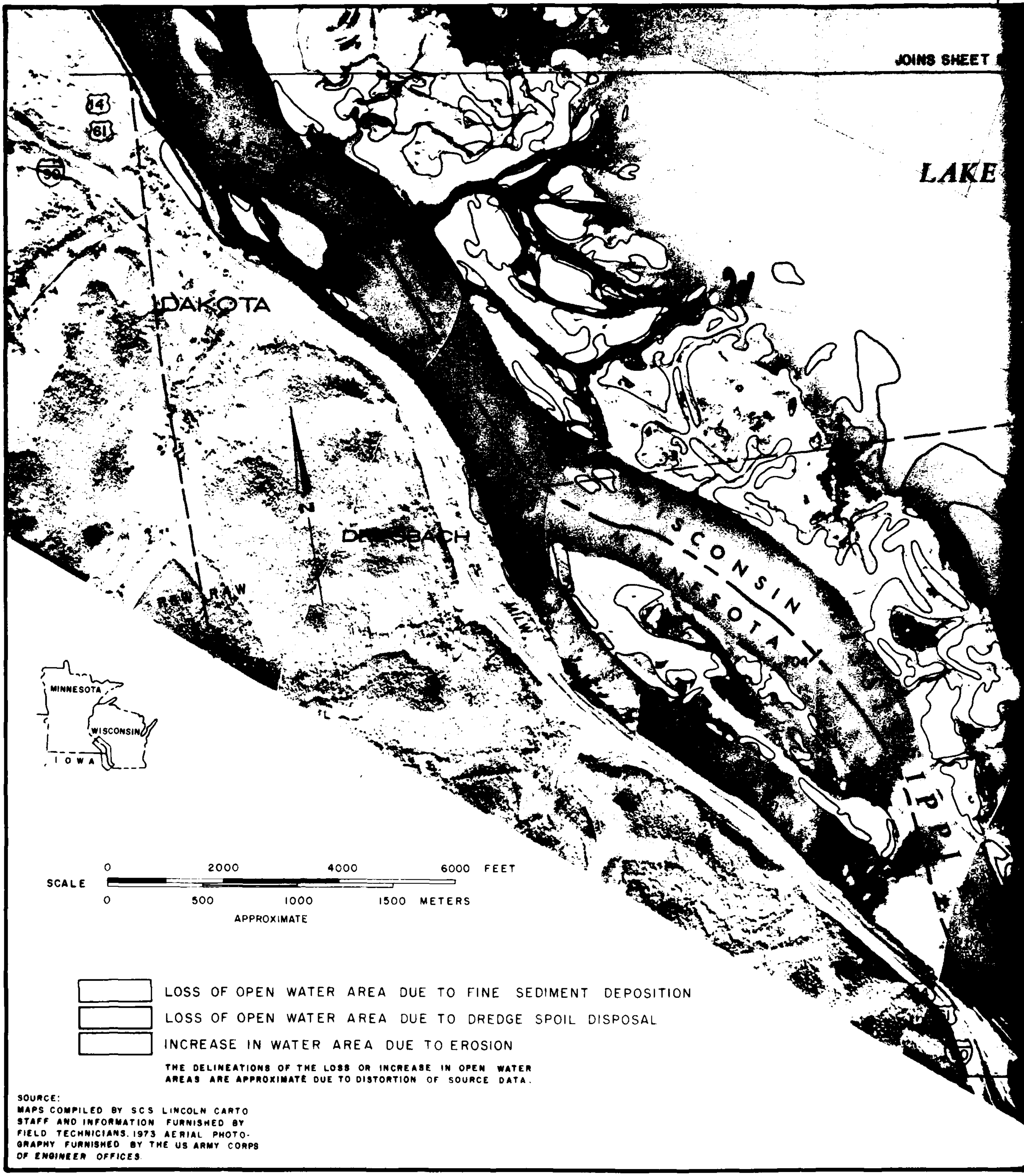
CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

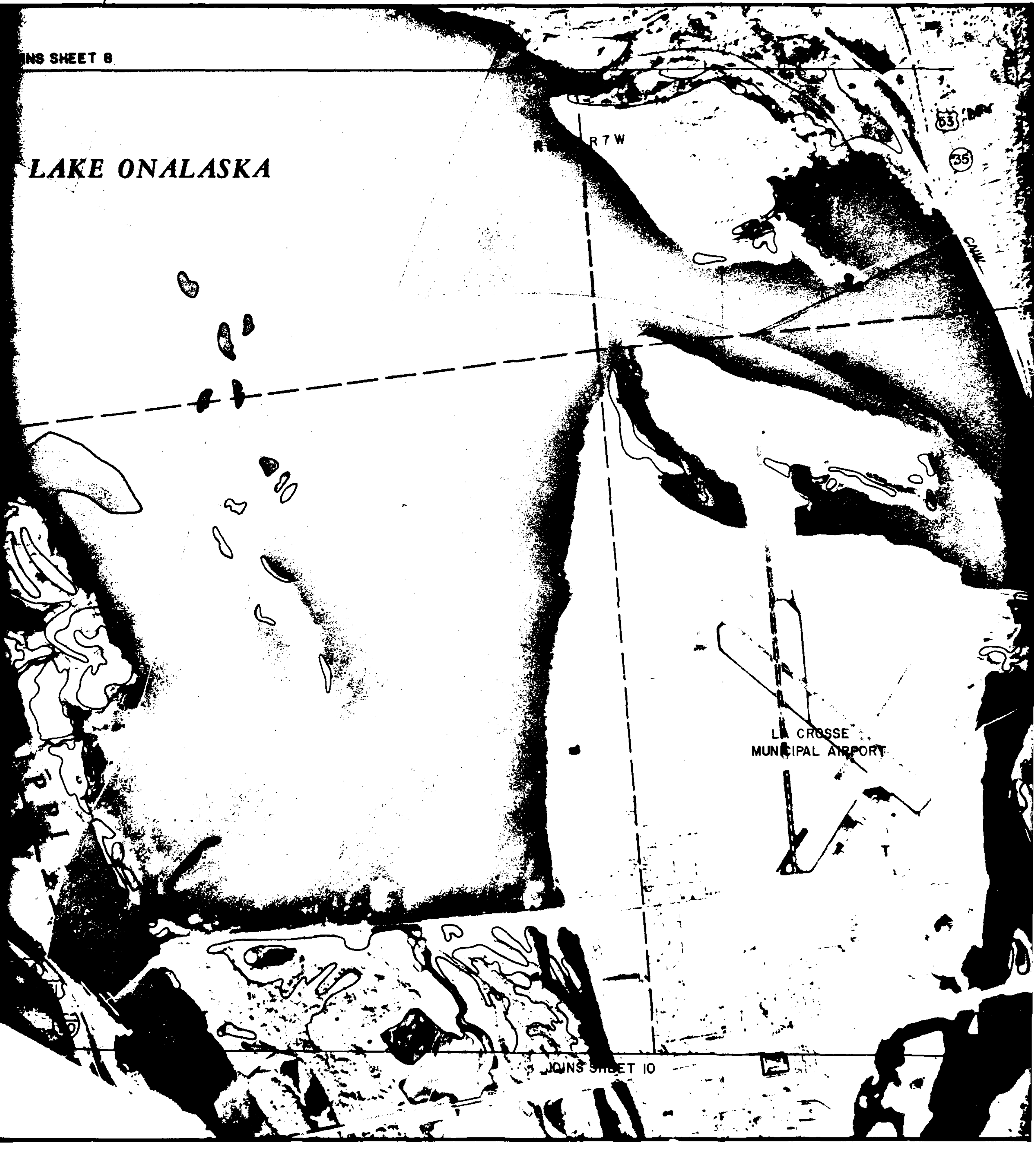
UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 6 OF 22 5,P-36,971

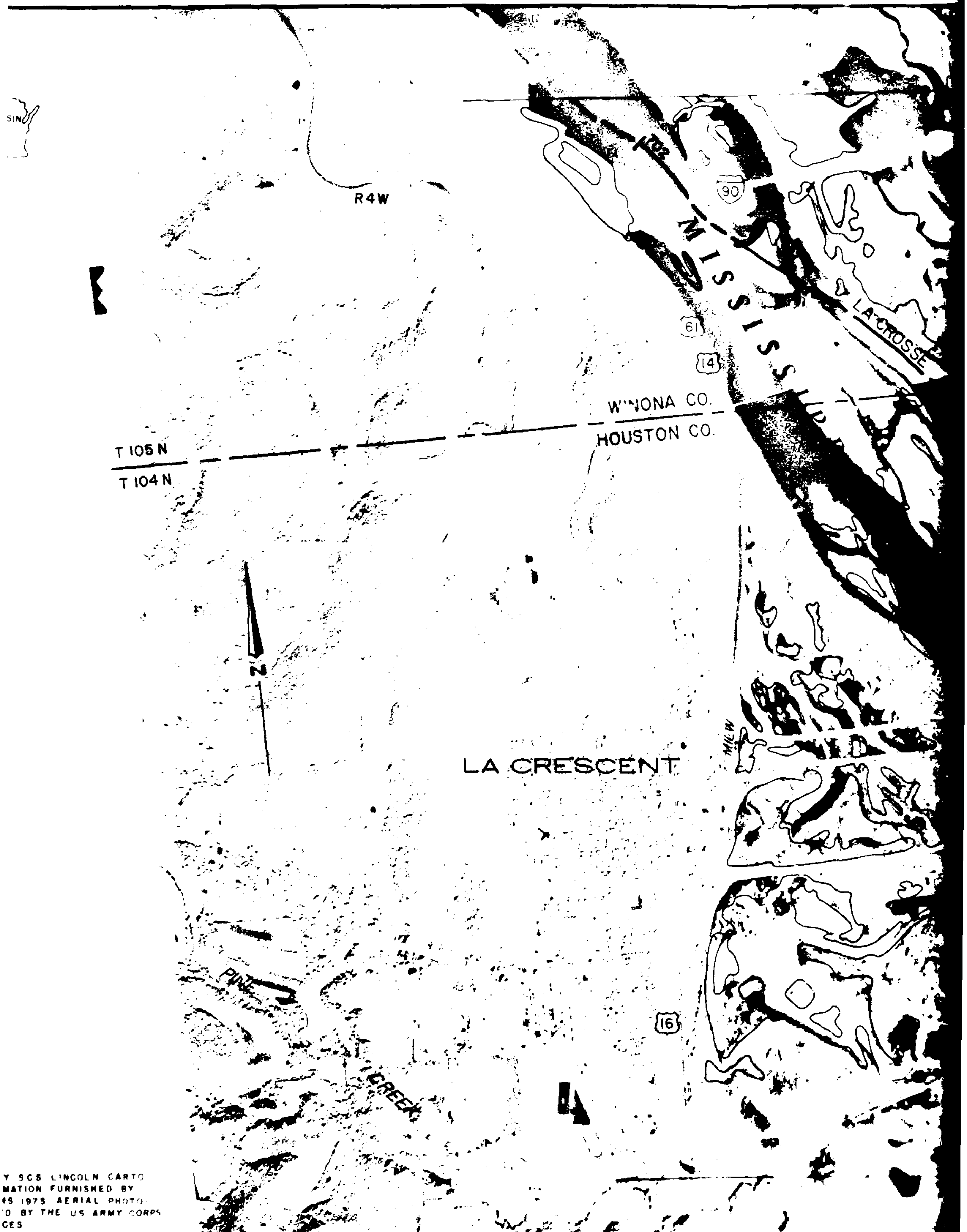


JOINS SHEET
LAKE
14
61
90
DAKOTA
N
MINNESOTA
WISCONSIN
IOWA
SCONSIN
NESOTA
SCALE
0 2000 4000 6000 FEET
0 500 1000 1500 METERS
APPROXIMATE
LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION
LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL
INCREASE IN WATER AREA DUE TO EROSION
THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA.
SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.



JOINS SHEET 8
LAKE ONALASKA
R 7 W
63
35
LA CROSSE
MUNICIPAL AIRPORT
JOINS SHEET 10


R 7 W
T17 N
T16 N
CANAL
BN
ONALASKA
LA CROSSE
MUNICIPAL AIRPORT
53
35
90
SHEET 10
U S DEPARTMENT OF AGRICULTURE
CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973
GREAT I
UPPER MISSISSIPPI RIVER BASIN
IOWA, MINNESOTA, SOUTH DAKOTA AND WISCONSIN
SHEET 9 OF 22
5,P-36,971

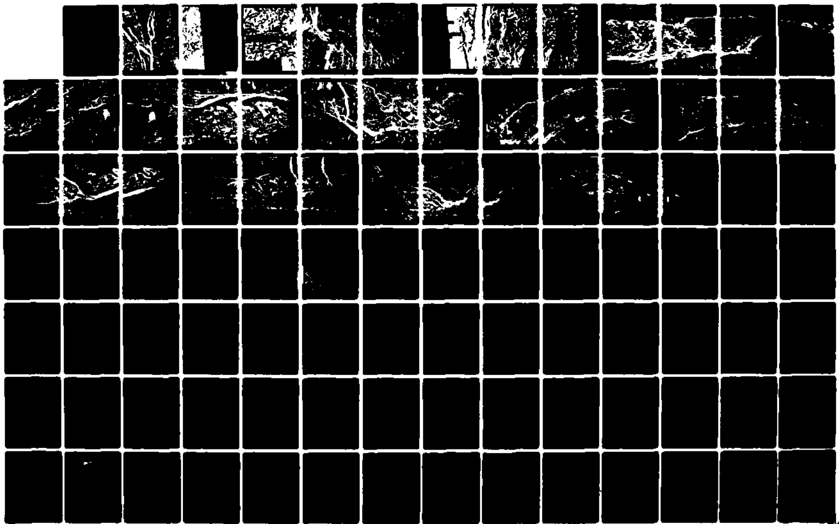


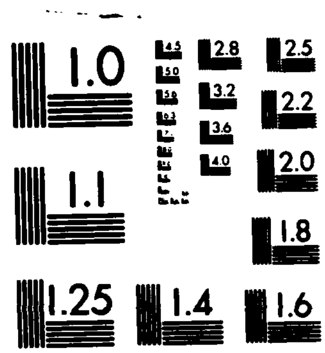
Y SCS LINCOLN CARTO
MATION FURNISHED BY
S 1973 AERIAL PHOTO
O BY THE US ARMY CORPS
CES

AD-A127 210 GREAT I STUDY OF THE UPPER MISSISSIPPI RIVER TECHNICAL APPENDIXES VOLUME 4 WATER QUALITY SEDIMENT & EROSION (U) GREAT RIVER ENVIRONMENTAL ACTION TEAM SEP 80

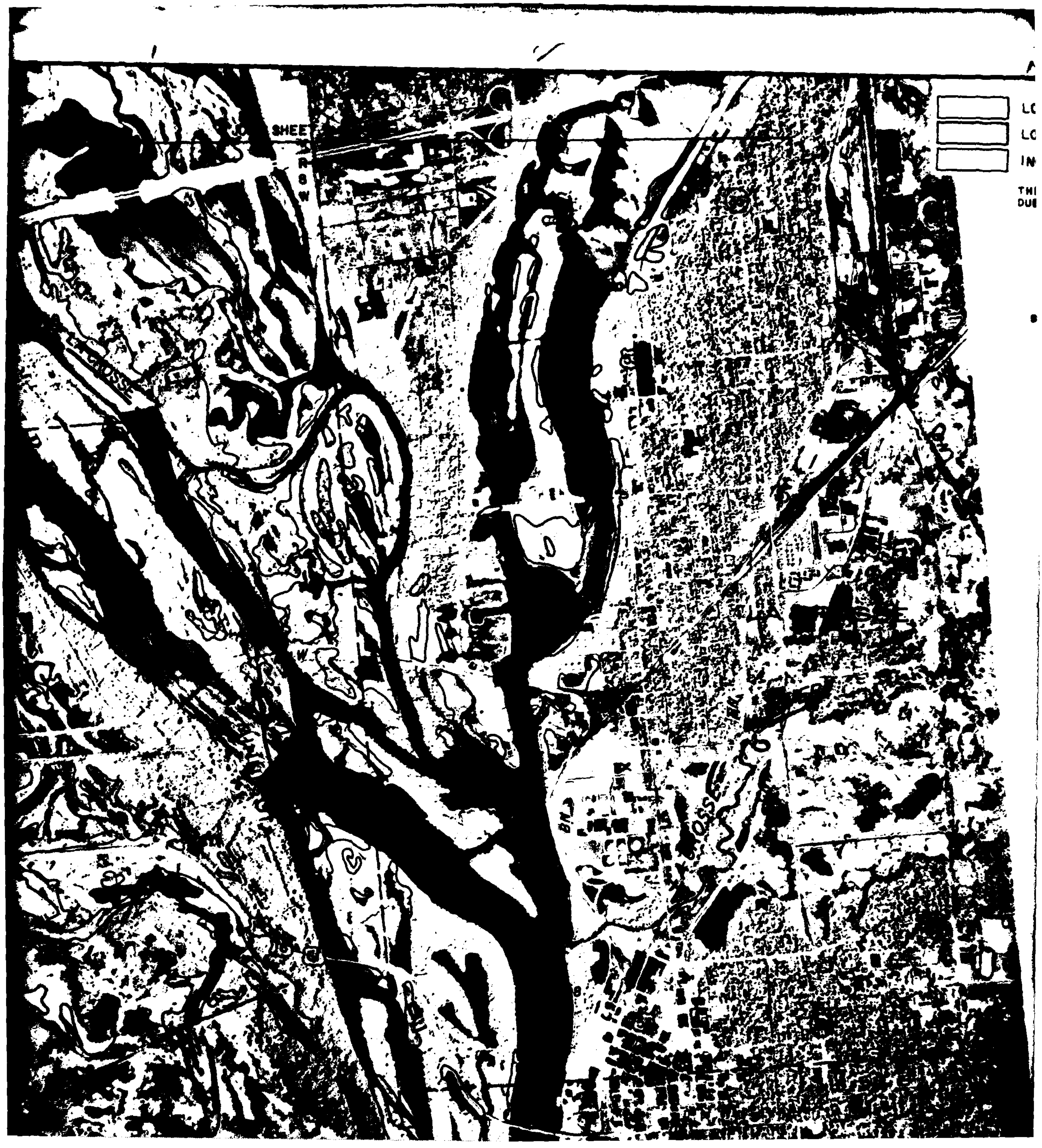
3/4

UNCLASSIFIED F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A


SHEET
LA CROSSE

LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION

LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL

INCREASE IN WATER AREA DUE TO EROSION

THE PHOTOGRAPHIC IMAGE MAY VARY FROM TRUE GROUND LOCATION
DUE TO INHERENT AERIAL PHOTOGRAPHIC DISPLACEMENT.

SCALE

0 2000 4000 6000 FEET

0 500 1000 1500 METERS

APPROXIMATE

U. S. DEPARTMENT OF AGRICULTURE

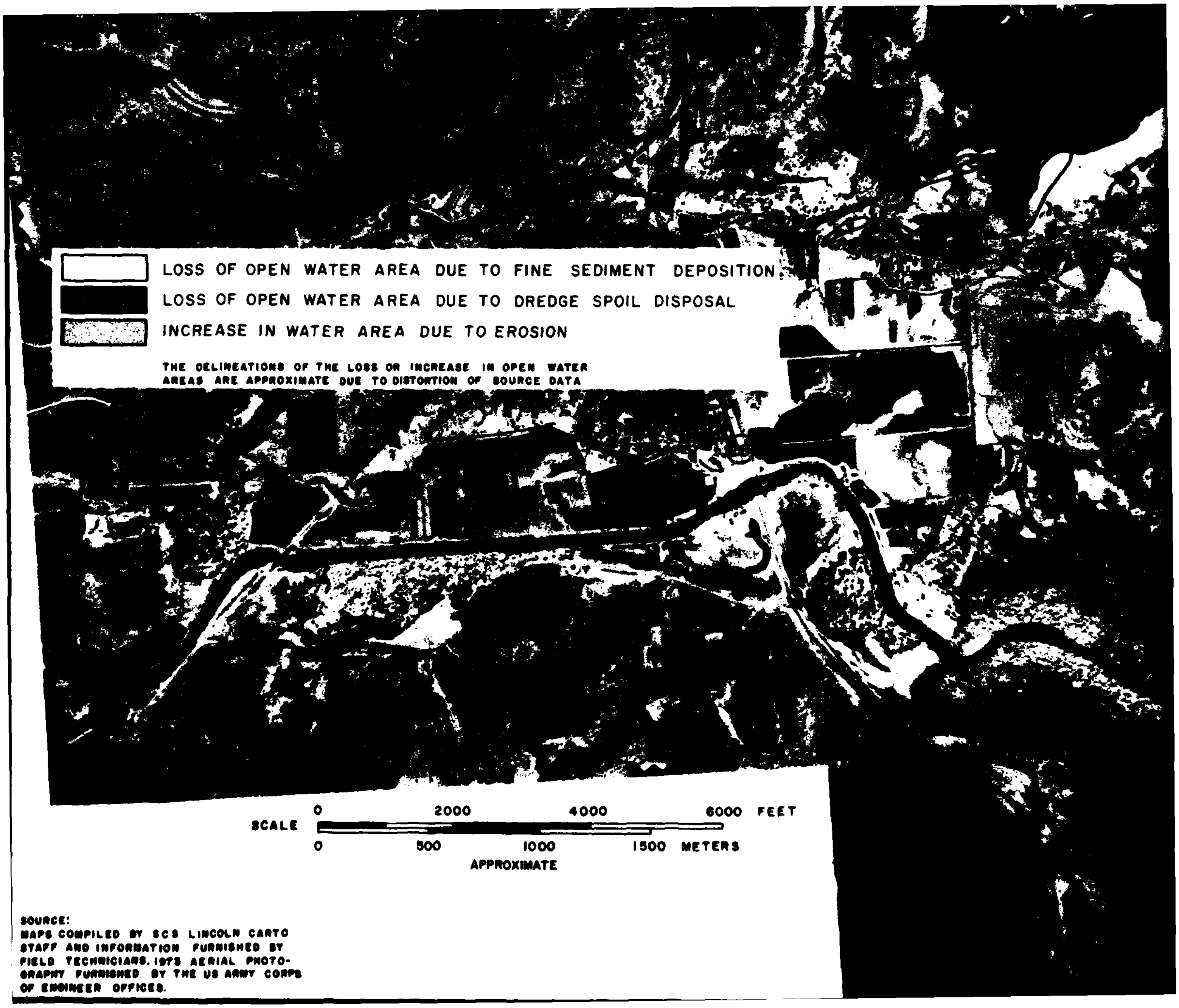
CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

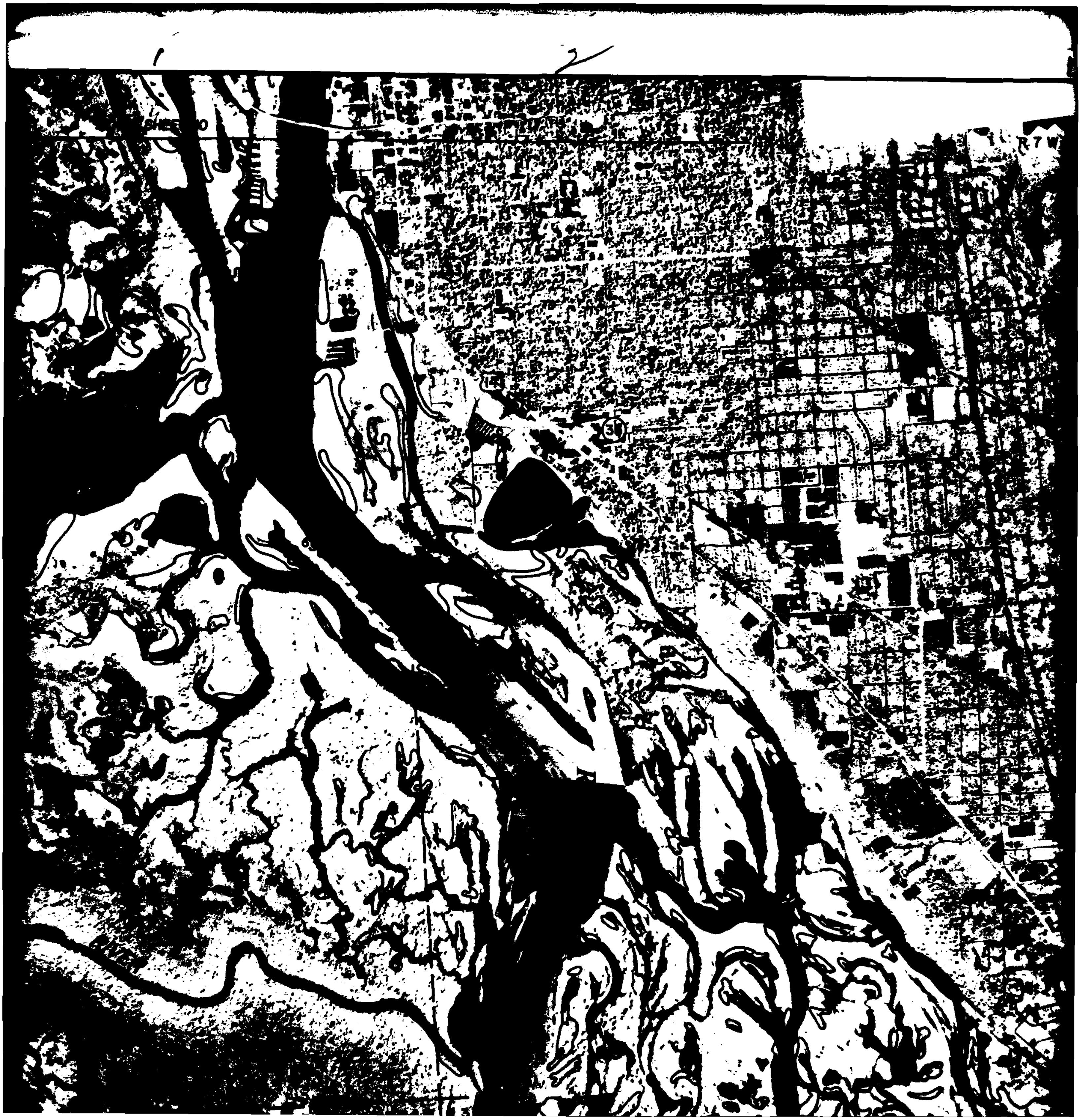
GREAT I

UPPER MISSISSIPPI RIVER BASIN

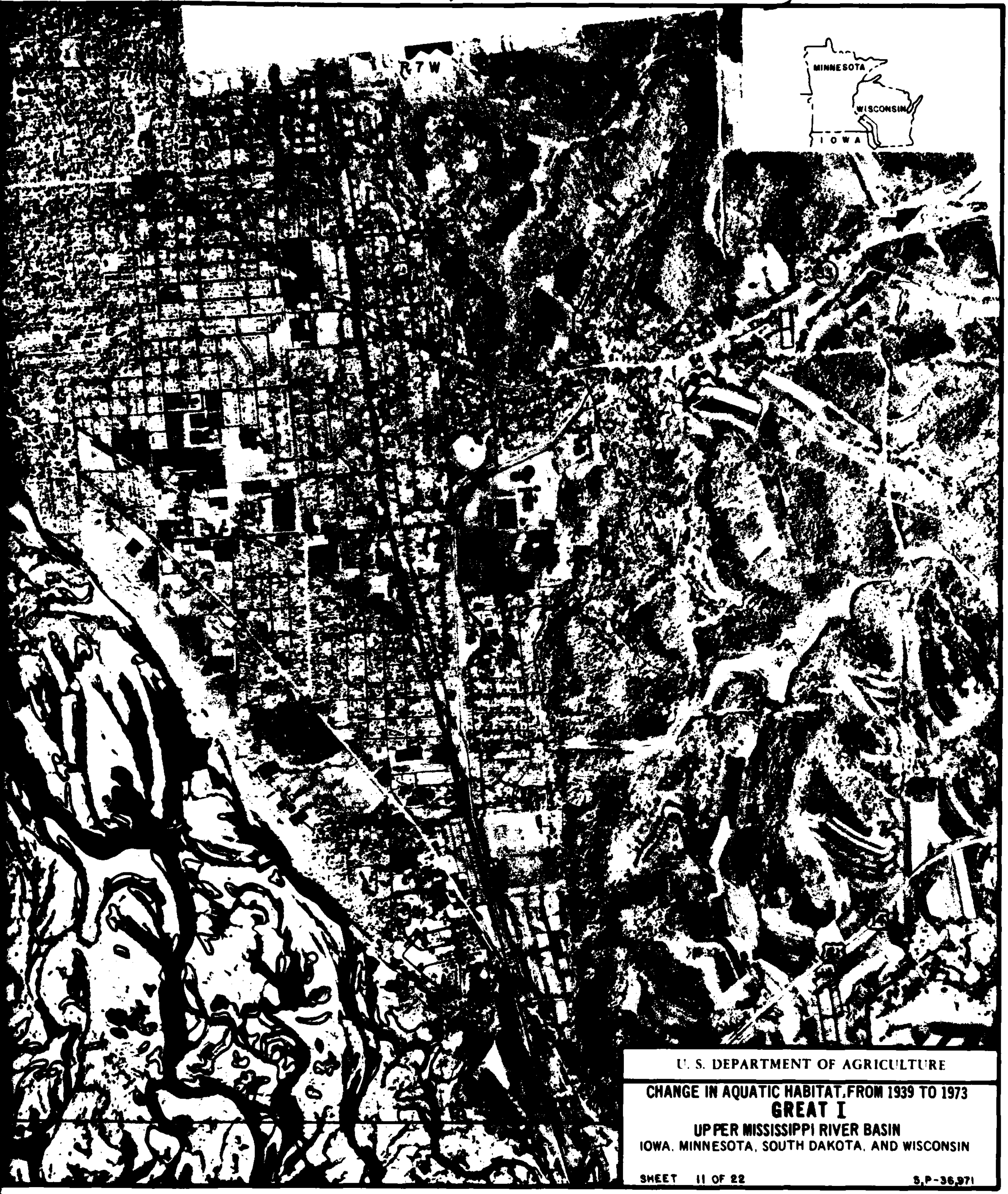
IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 10 OF 23


LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION
LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL
INCREASE IN WATER AREA DUE TO EROSION
THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA
SCALE
0 2000 4000 6000 FEET
0 500 1000 1500 METERS
APPROXIMATE
SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.



R 7 W



U. S. DEPARTMENT OF AGRICULTURE

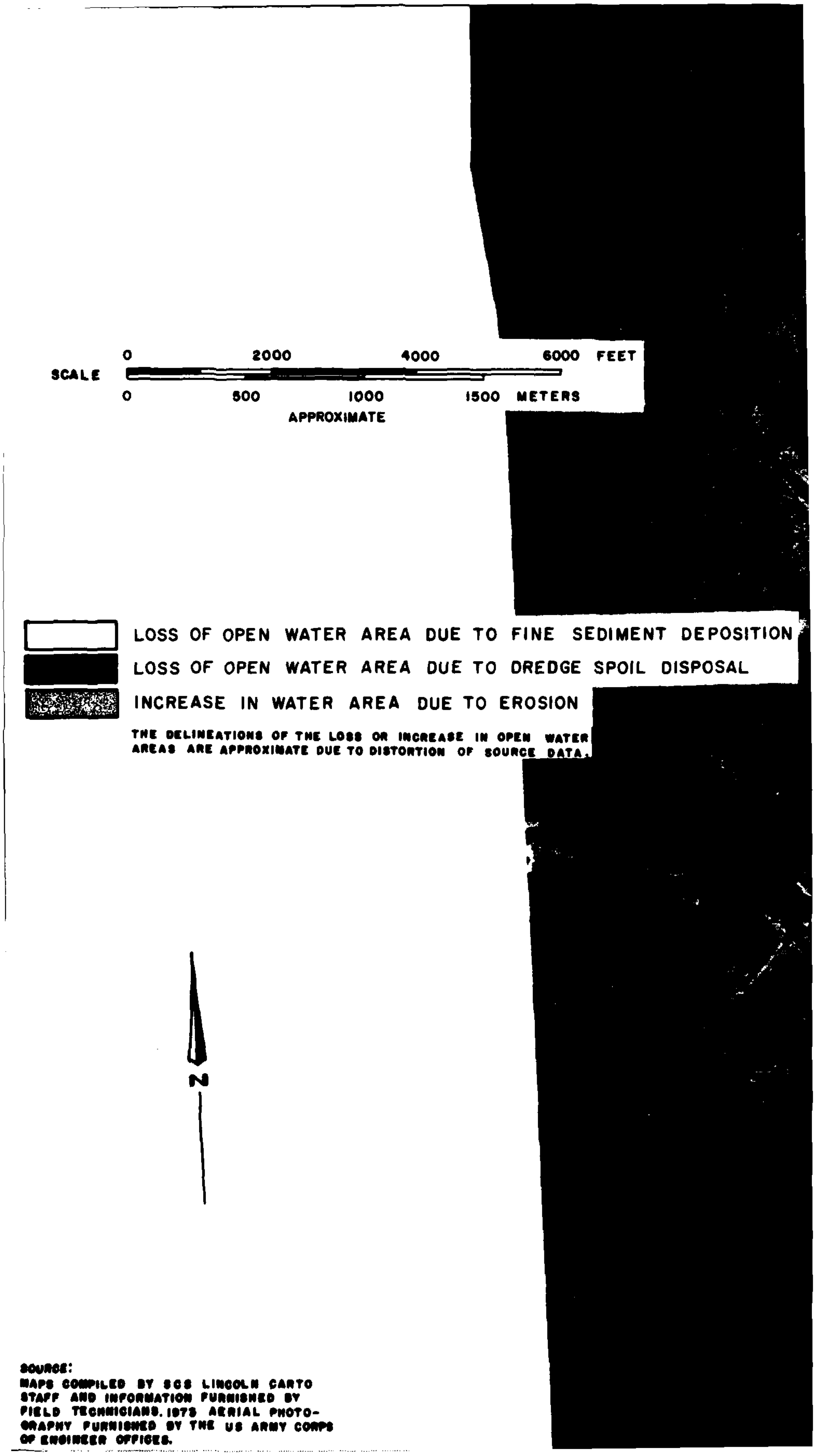
CHANGE IN AQUATIC HABITAT, FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 11 OF 22 5,P-36,971



SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTO-GRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.

U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

U. S. DEPARTMENT OF AGRICULTURE

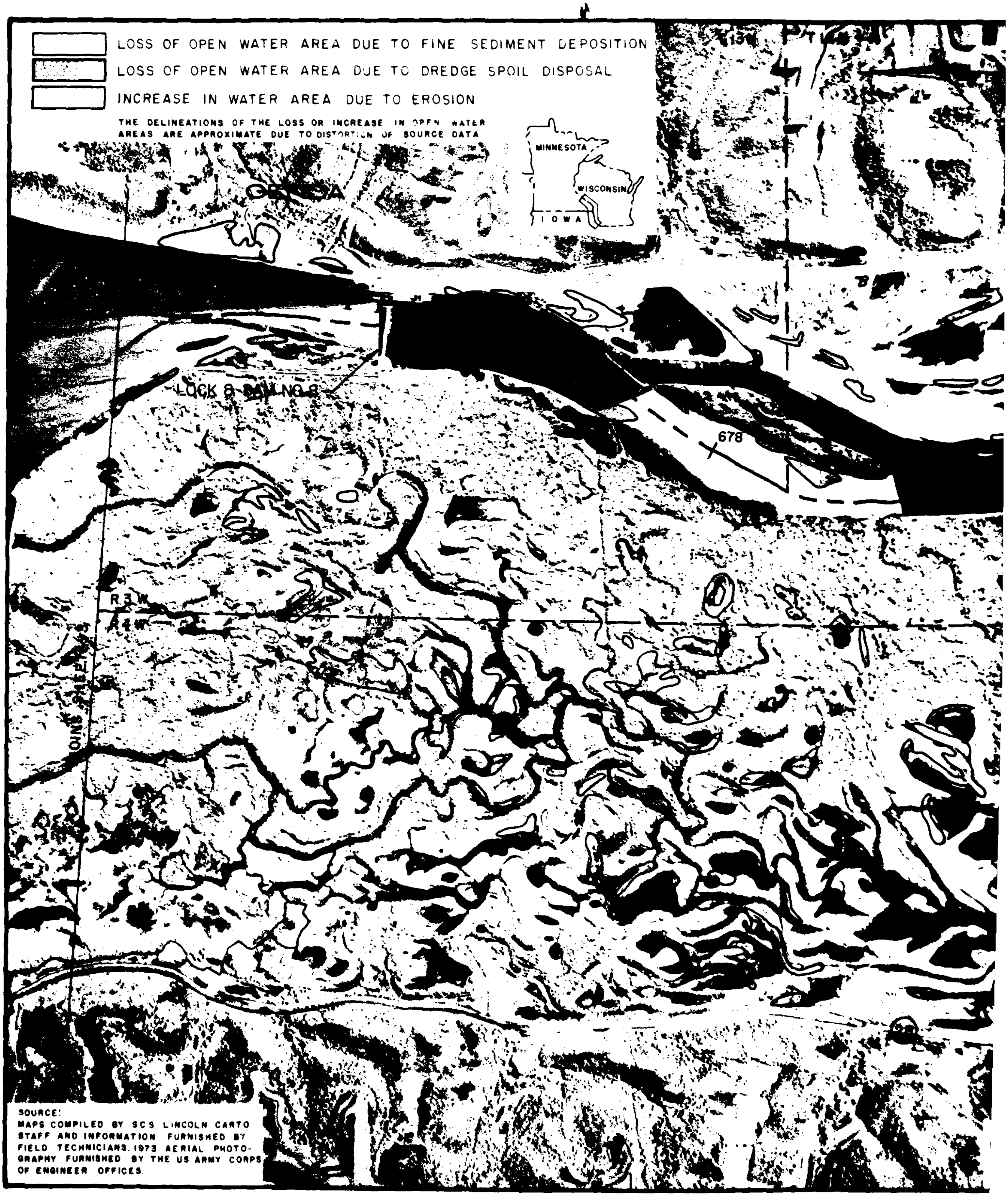
CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 13 OF 22 5,P-36,971



LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION
LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL
INCREASE IN WATER AREA DUE TO EROSION
THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA
MINNESOTA
WISCONSIN
IOWA
LOCK 8 DAM NO 8
678
R 3 W
R 4 W
SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.

674
VERNON
HOUSTON CO
ALLAMAKEE CO
35
T101N
SCALE
0
2000
4000
6000 FEET
0
500
1000
1500 METERS
APPROXIMATE

U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

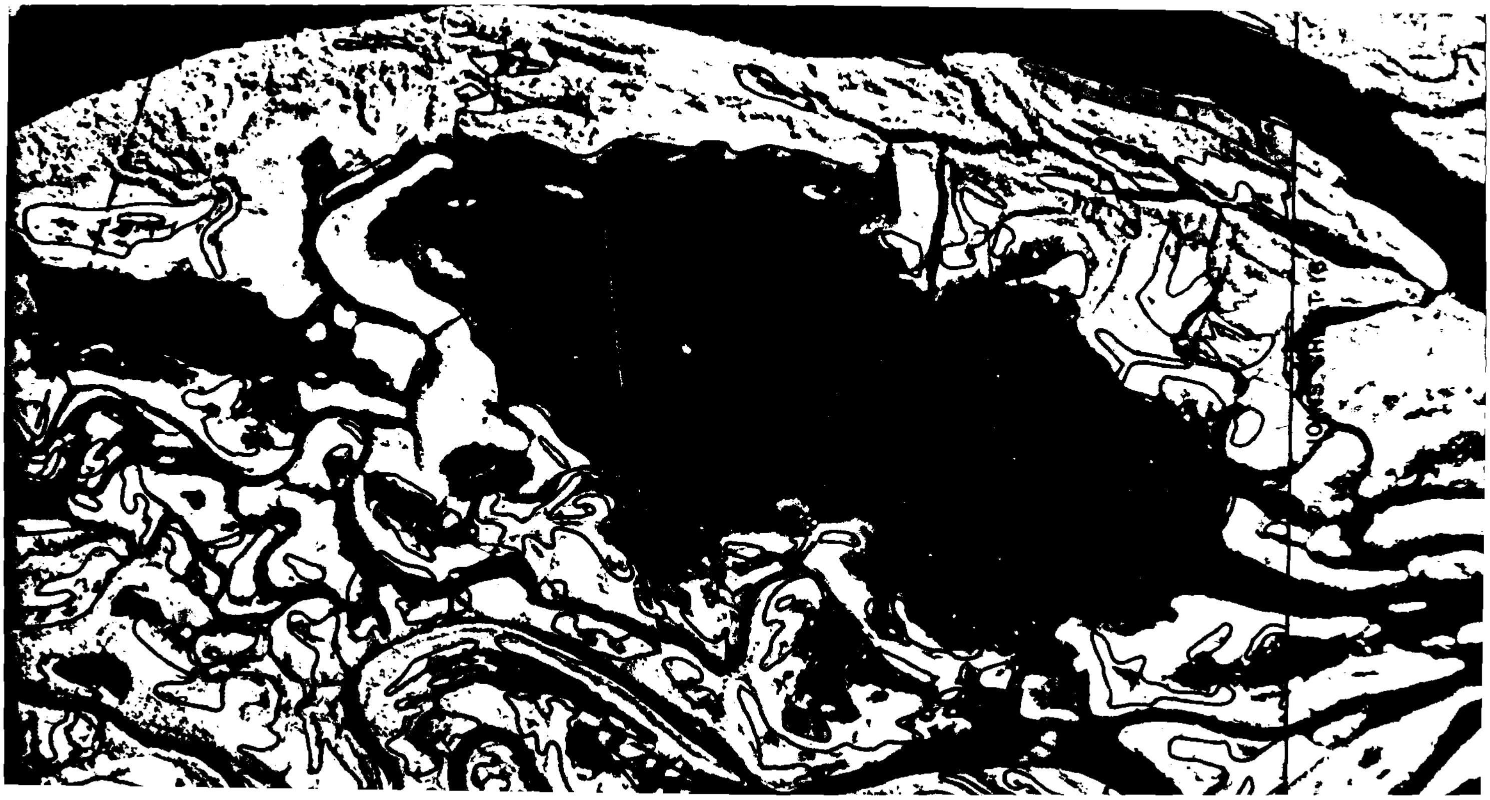
GREAT I

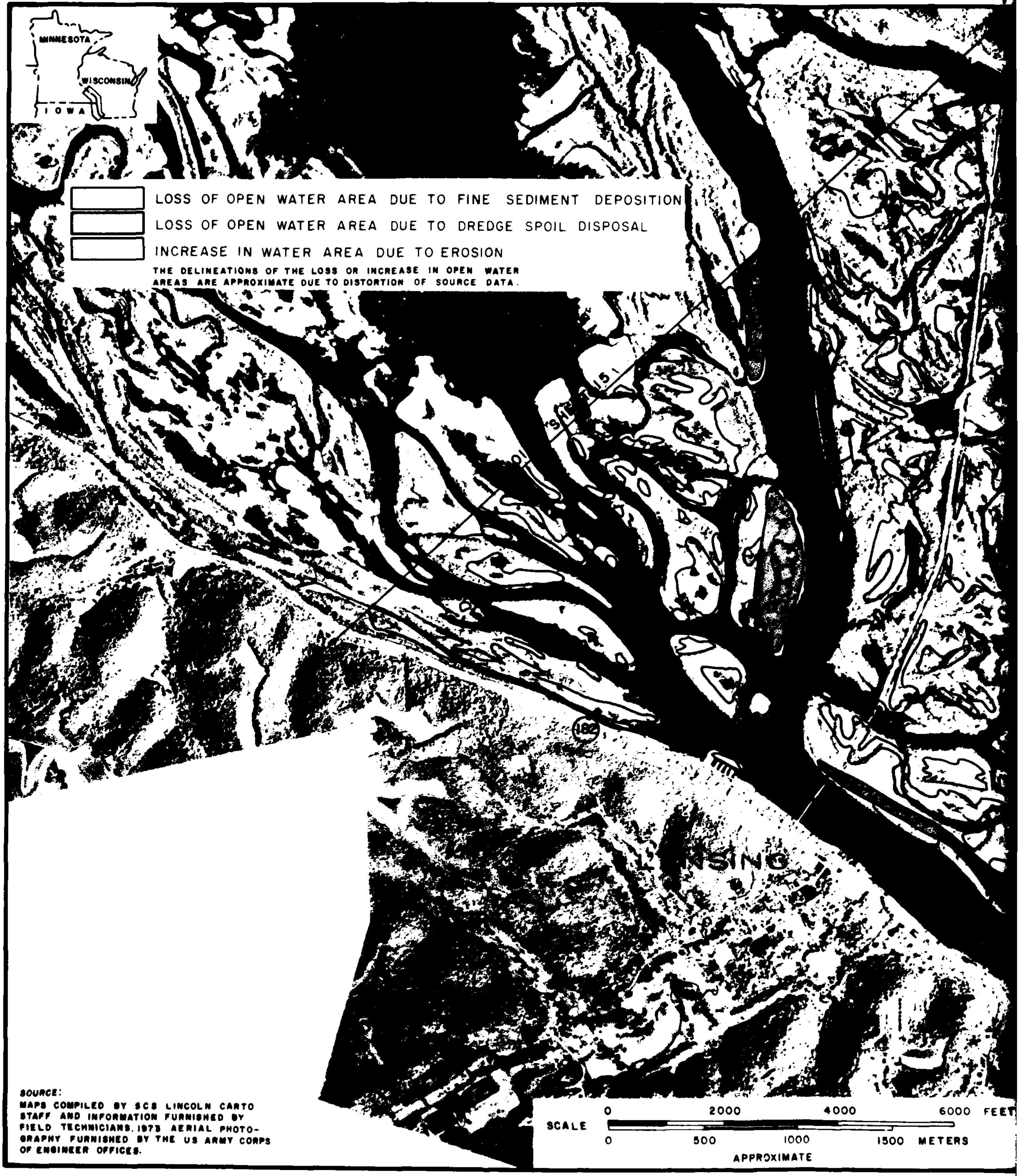
UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

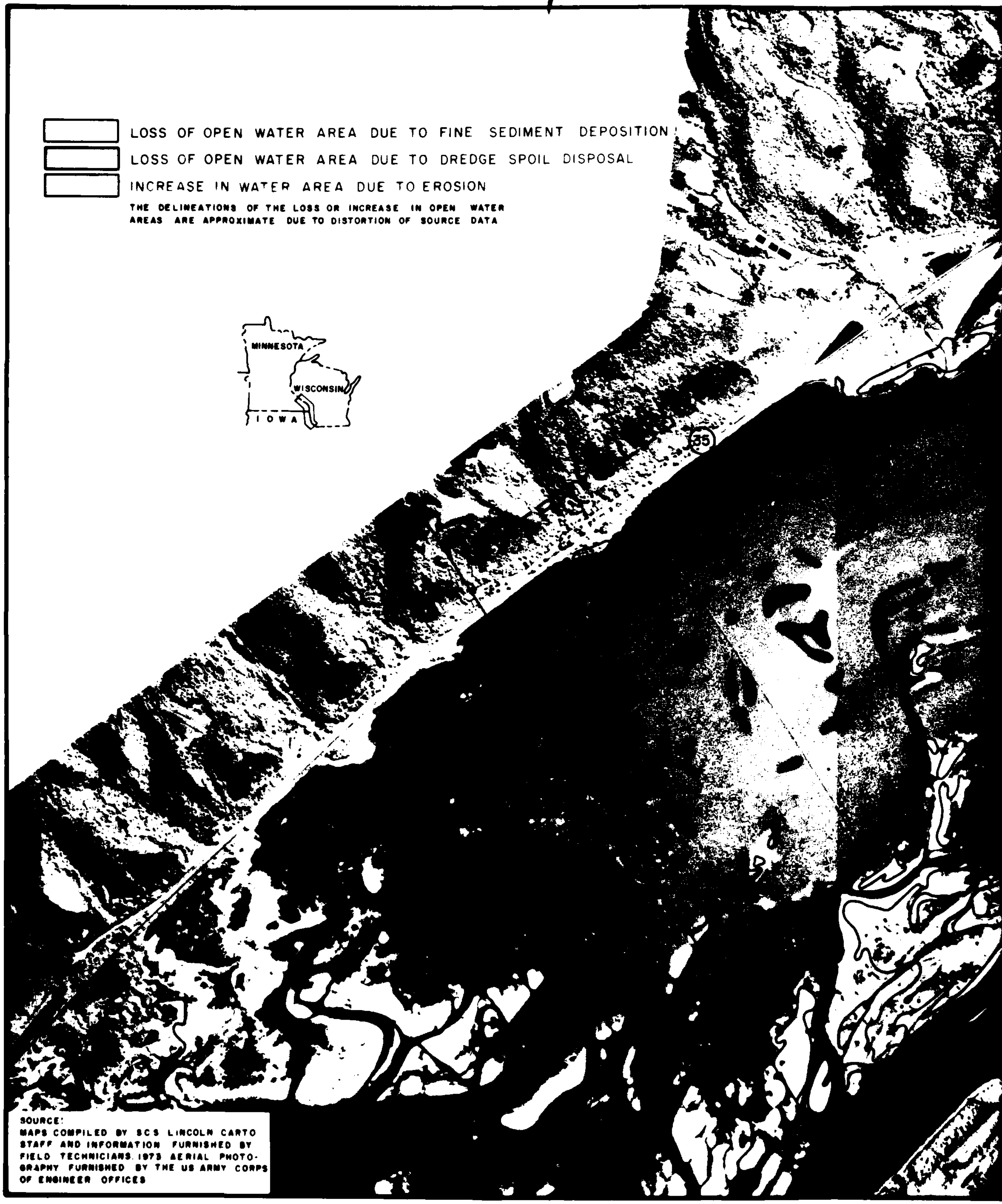
SHEET 14 OF 22 5,P-36,971

SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.




MINNESOTA
WISCONSIN
IOWA
LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION
LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL
INCREASE IN WATER AREA DUE TO EROSION
THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA.
182
SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.
SCALE
0 2000 4000 6000 FEET
0 500 1000 1500 METERS
APPROXIMATE


JOINS SHEET 17
U S DEPARTMENT OF AGRICULTURE
CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973
GREAT I
UPPER MISSISSIPPI RIVER BASIN
IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN
SHEET 16 OF 22
5,P-36,971


LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION
LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL
INCREASE IN WATER AREA DUE TO EROSION
THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA
MINNESOTA
WISCONSIN
IOWA
35
SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES

1 3

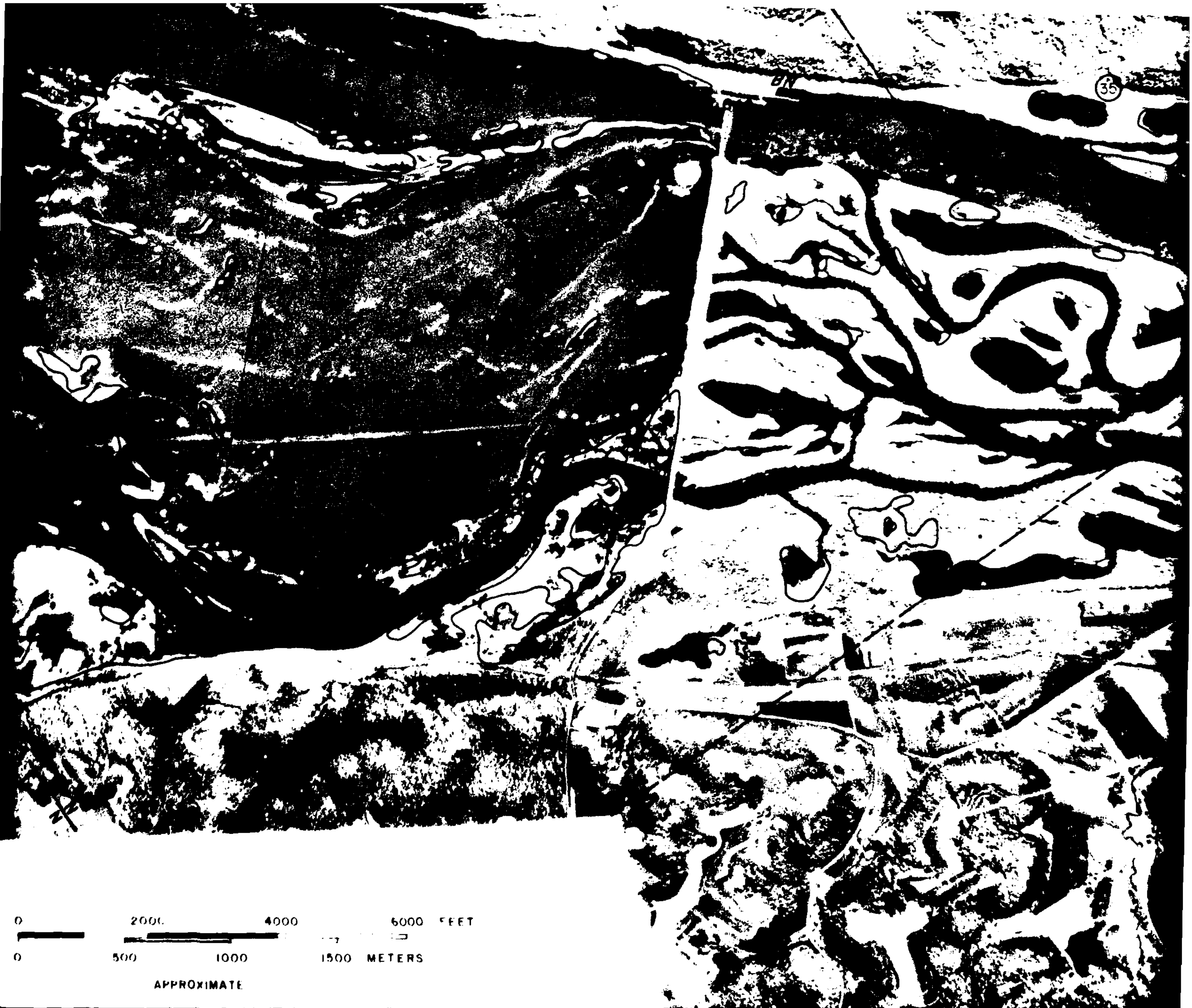
U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973
GREAT I
UPPER MISSISSIPPI RIVER BASIN
IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 17 OF 22 5,P-36,971

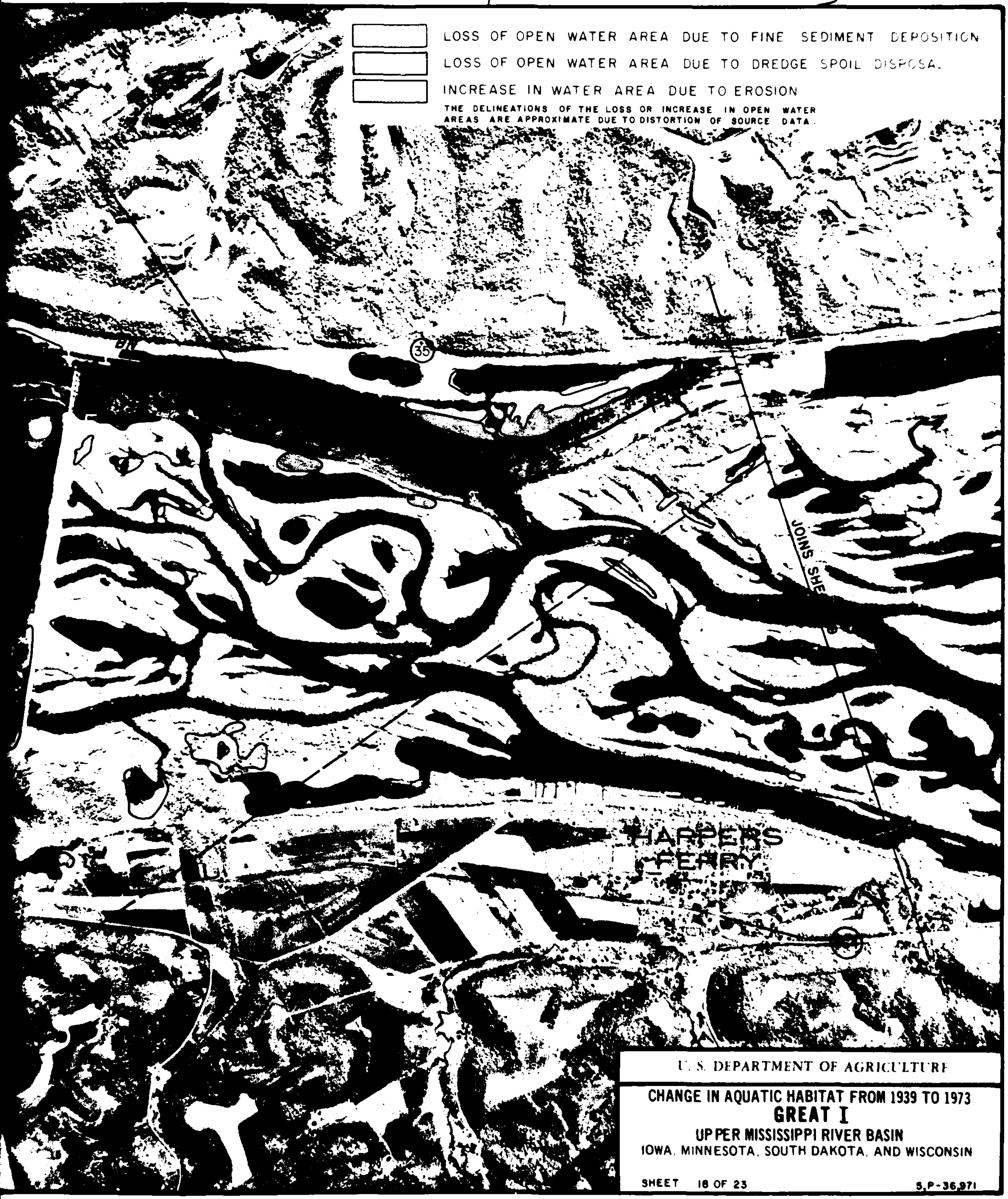
2000 4000 6000 FEET
00 1000 1500 METERS
APPROXIMATE


MINNESOTA
WISCONSIN
IOWA
LYNXVI
BN
JOIN
MILW
SOURCE:
MAPS COMP LED BY SCS LINCOLN CARTO
STAFF INFORMATION FURNISHED BY
FIELD NICIANS. 973 AERIAL PHOTO-
GRAPH URNISHED BY THE US ARMY CORPS
OF ENGINEER OFFICES
SCALE
0
0



35
0 2000 4000 6000 FEET
0 500 1000 1500 METERS
APPROXIMATE

1 3



U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

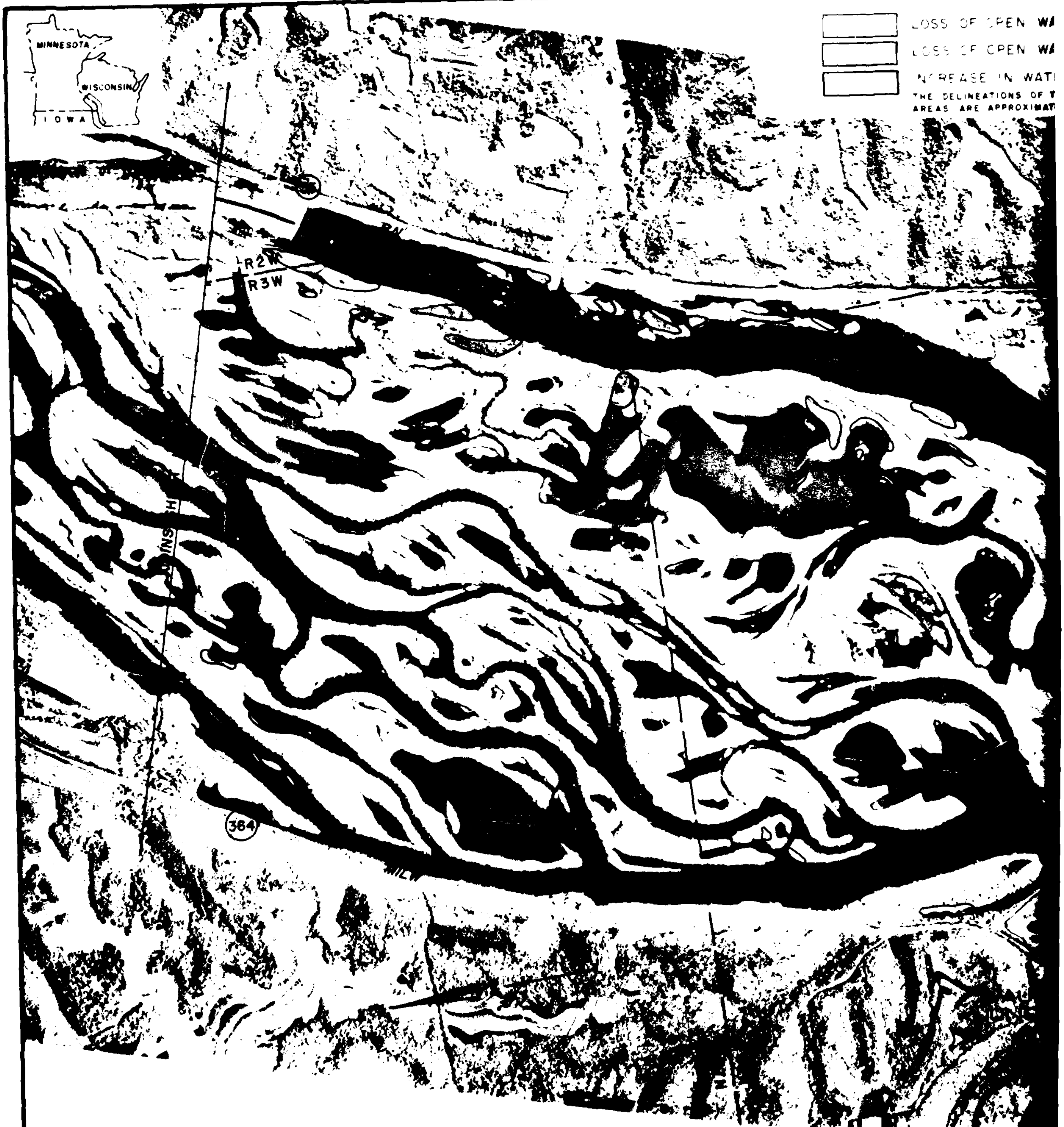
GREAT I

UPPER MISSISSIPPI RIVER BASIN

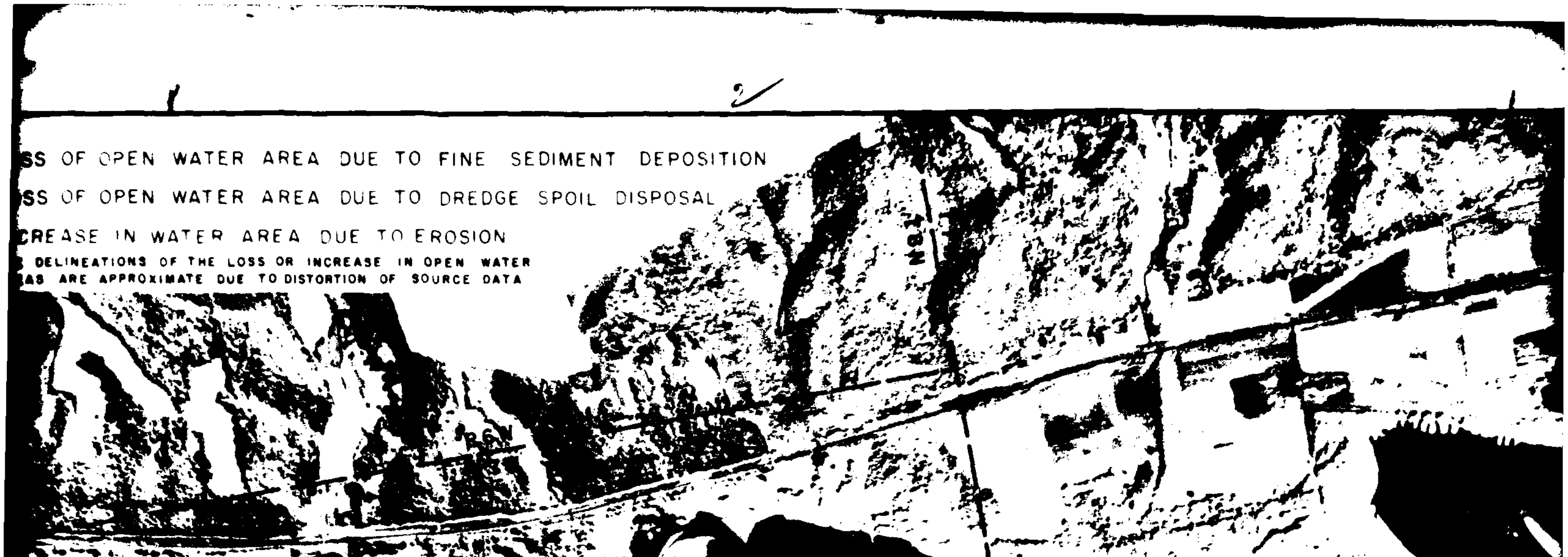
IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 18 OF 23

5,P-36,971



SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES


SS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION
SS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL
CREASE IN WATER AREA DUE TO EROSION
DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER
AS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA
SPRING L
MILW

U. S. DEPARTMENT OF AGRICULTURE

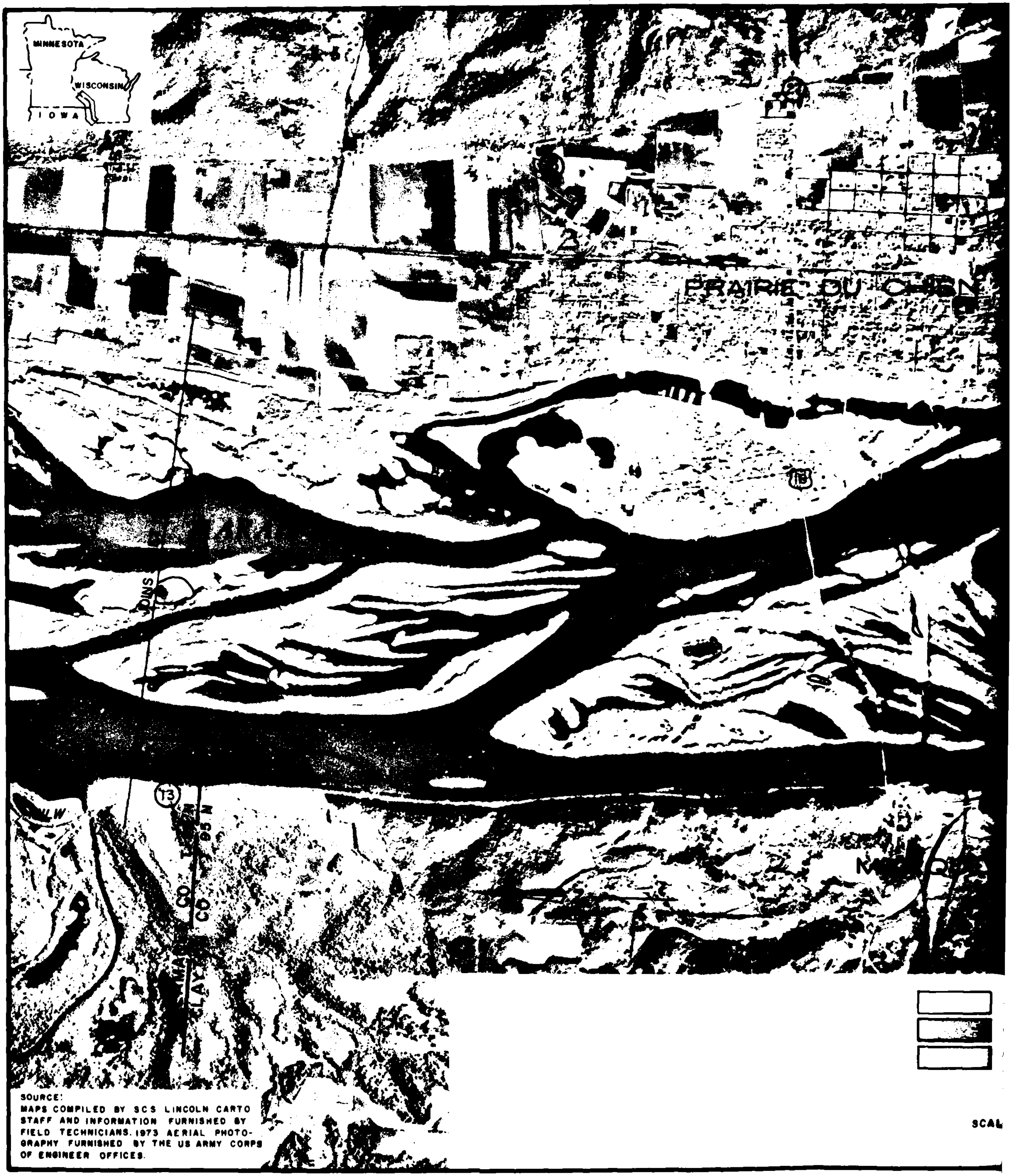
CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 19 OF 22 5,P-36,971



SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.

1 2

LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION

LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL

INCREASE IN WATER AREA DUE TO EROSION

THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA.

SCALE 0 2000 4000 6000 FEET

0 500 1000 1500 METERS

APPROXIMATE

3

EPOSITION

OSAL

U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

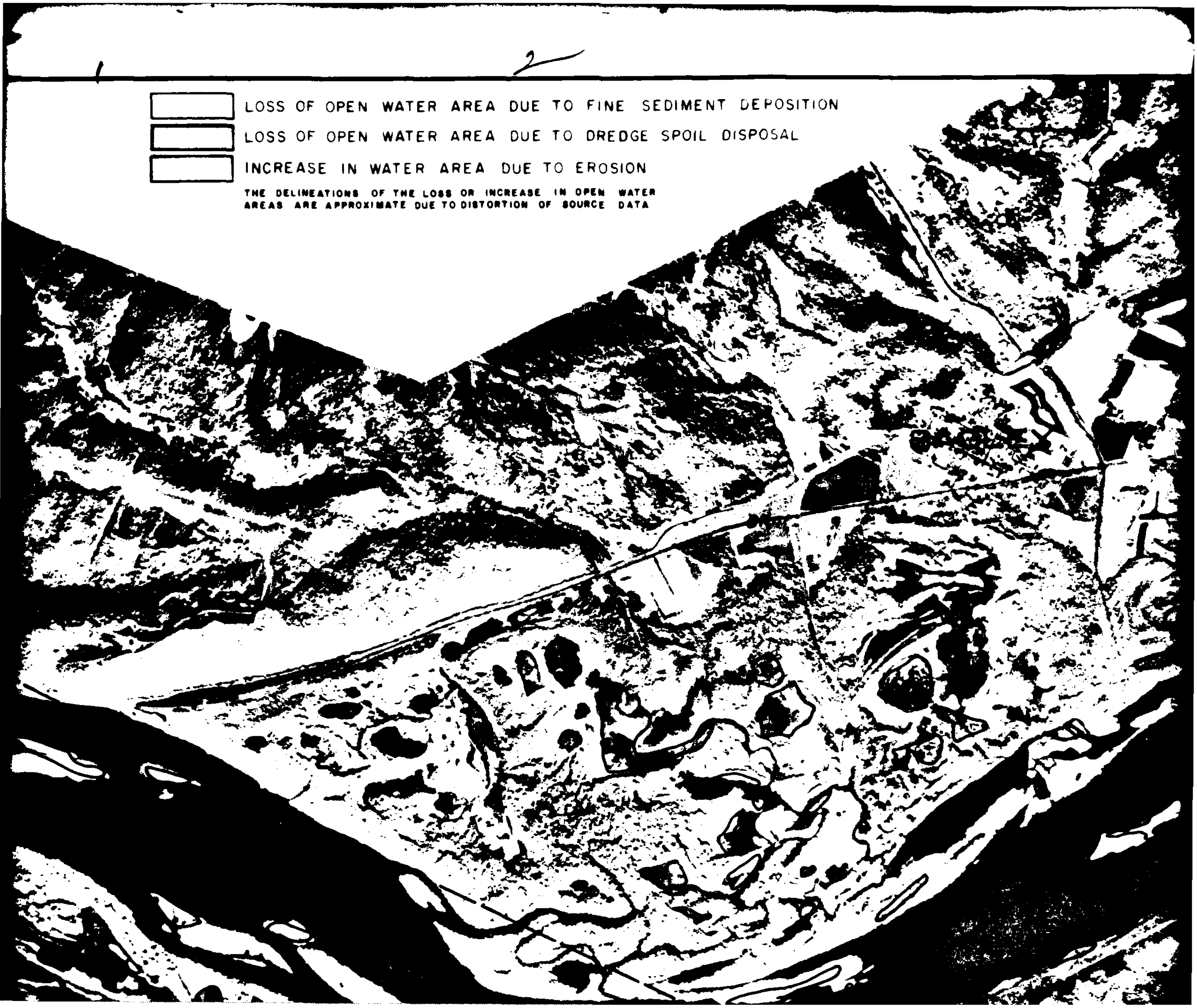
GREAT I

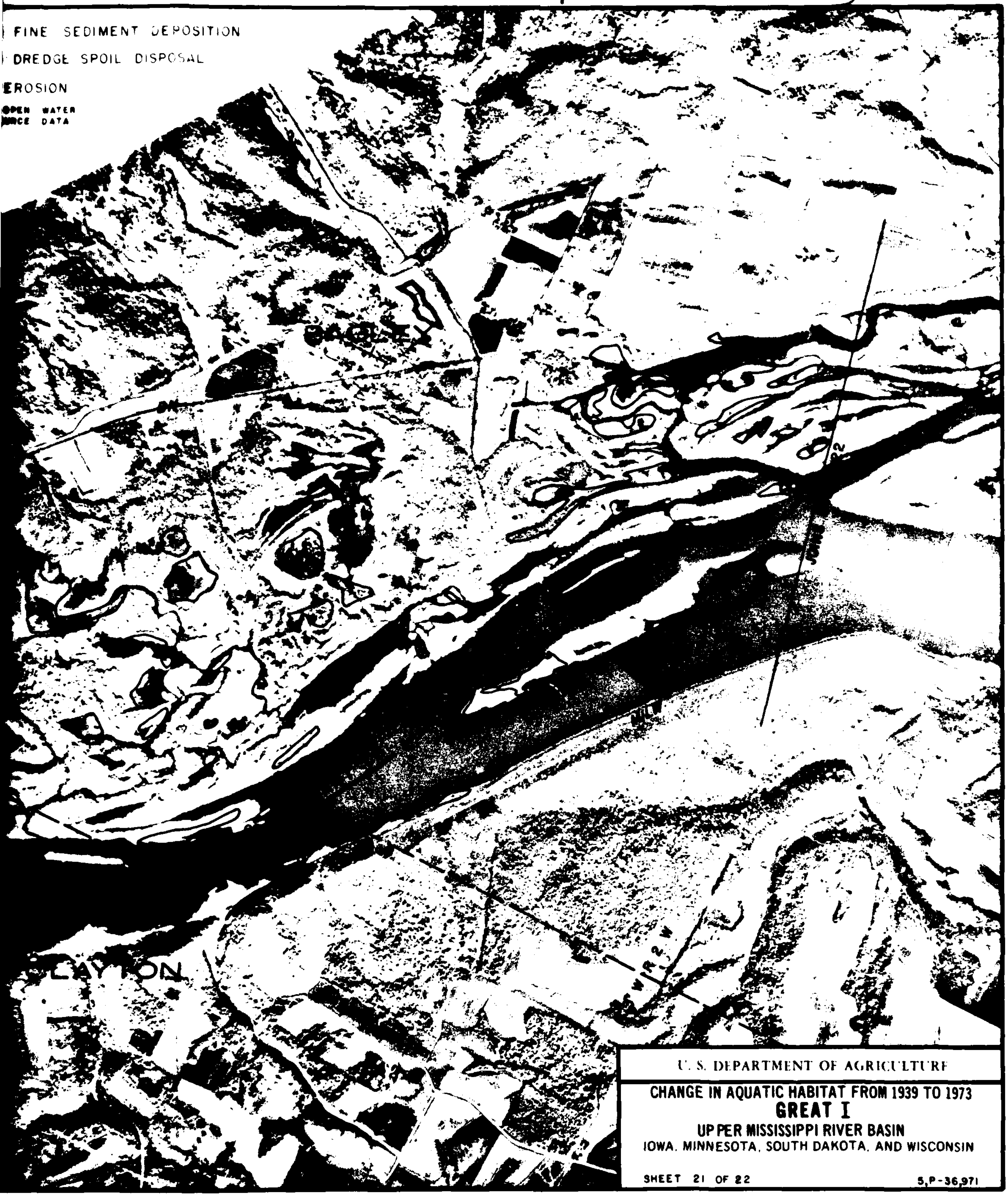
UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 20 OF 22 5,P-36,971


MINNESOTA
WISCONSIN
IOWA
WYAL
SCAL
SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.


LOSS OF OPEN WATER AREA DUE TO FINE SEDIMENT DEPOSITION
LOSS OF OPEN WATER AREA DUE TO DREDGE SPOIL DISPOSAL
INCREASE IN WATER AREA DUE TO EROSION
THE DELINEATIONS OF THE LOSS OR INCREASE IN OPEN WATER AREAS ARE APPROXIMATE DUE TO DISTORTION OF SOURCE DATA



U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 21 OF 22

5,P-36,971


MINNESOTA
WISCONSIN
IOWA
SOURCE:
MAPS COMPILED BY SCS LINCOLN CARTO STAFF AND INFORMATION FURNISHED BY FIELD TECHNICIANS. 1973 AERIAL PHOTOGRAPHY FURNISHED BY THE US ARMY CORPS OF ENGINEER OFFICES.
SCALE
0 2000 4000 6000 FEET
0 500 1000 1500 METERS
APPROXIMATE

LOSS OF

LOSS OF

INCREAS

THE DELI

AREAS AR

6000 FEET

METERS

U. S. DEPARTMENT OF AGRICULTURE

CHANGE IN AQUATIC HABITAT FROM 1939 TO 1973

GREAT I

UPPER MISSISSIPPI RIVER BASIN

IOWA, MINNESOTA, SOUTH DAKOTA, AND WISCONSIN

SHEET 22 OF 22 5,P-36,971.

CHAPTER VI

EROSION AND LAND TREATMENT

EROSION

Geologic erosion occurs when water, wind, or other erosive agents move soil or rock from slopes that have not been disturbed by man. Geologic erosion created many of our natural terrain features including the Mississippi River valley which was created by the erosive forces of ancient glacial meltwaters.

The greatest amount of erosion is man-made or accelerated erosion that has resulted from the practices of agriculture and urban development. When the natural covers of grasses and forests were removed by the early settlers, potential for erosion increased enormously. The process of soil erosion by water consists of three principal steps:

1. The loosening of soil particles by the impact of rainfall or the scouring action of running water.

2. Movement of the detached particles by flowing water.

3. Deposition of the particles at new locations.

Whenever rain falls faster than it can soak in, a sheet of water collects on the surface and moves downhill. The water dislodges the soil and keeps it suspended in the moving sheet of water feeding into little streams. The finest mineral and organic particles are carried in the runoff leaving the coarse or less fertile particles behind. This action of rainfall and flowing water which removes minute layers of soil is known as sheet and rill erosion. This type of erosion is responsible for the great majority of the soil erosion in the GREAT I study area.

As small streamlets or rills carry soil, the abrasive particles that the water carries in suspension may help the water to scour the sides and bottom of the channels. As these rills form into larger streams, the water flows faster and the scouring action increases. The result of the scouring action in these larger channels is gully erosion. It is in the larger gullies and streams that the gullies form that the water velocities become sufficiently intense to carry the large coarse sand particles which eventually must be dredged from the river channel.

The final step in the erosion process is sediment deposition. Deposition occurs as the water flow slows in the river channels and backwaters. Soil particles are sorted in the deposition process primarily as a function of flow velocities. The ability of the river to transport soil particles or sediment downstream (in suspension or along the bottom) is called carrying capacity. Because impoundment of the Mississippi River has created a series of slack-water pools where flow velocities are decreased as tributaries near the river, their flow also tends to decrease. The result is that the heaviest sediment particles being transported downstream will drop out near the mouth of the tributaries, often forming sand deltas or shoals in the main channel. This accumulation of sand requires dredging to maintain the 9-foot navigation channel. Finer sediment particles remain in suspension as long as the river carrying capacity supports them. When the current velocity further slows in backwater areas or open water pools, the fine particles settle out.

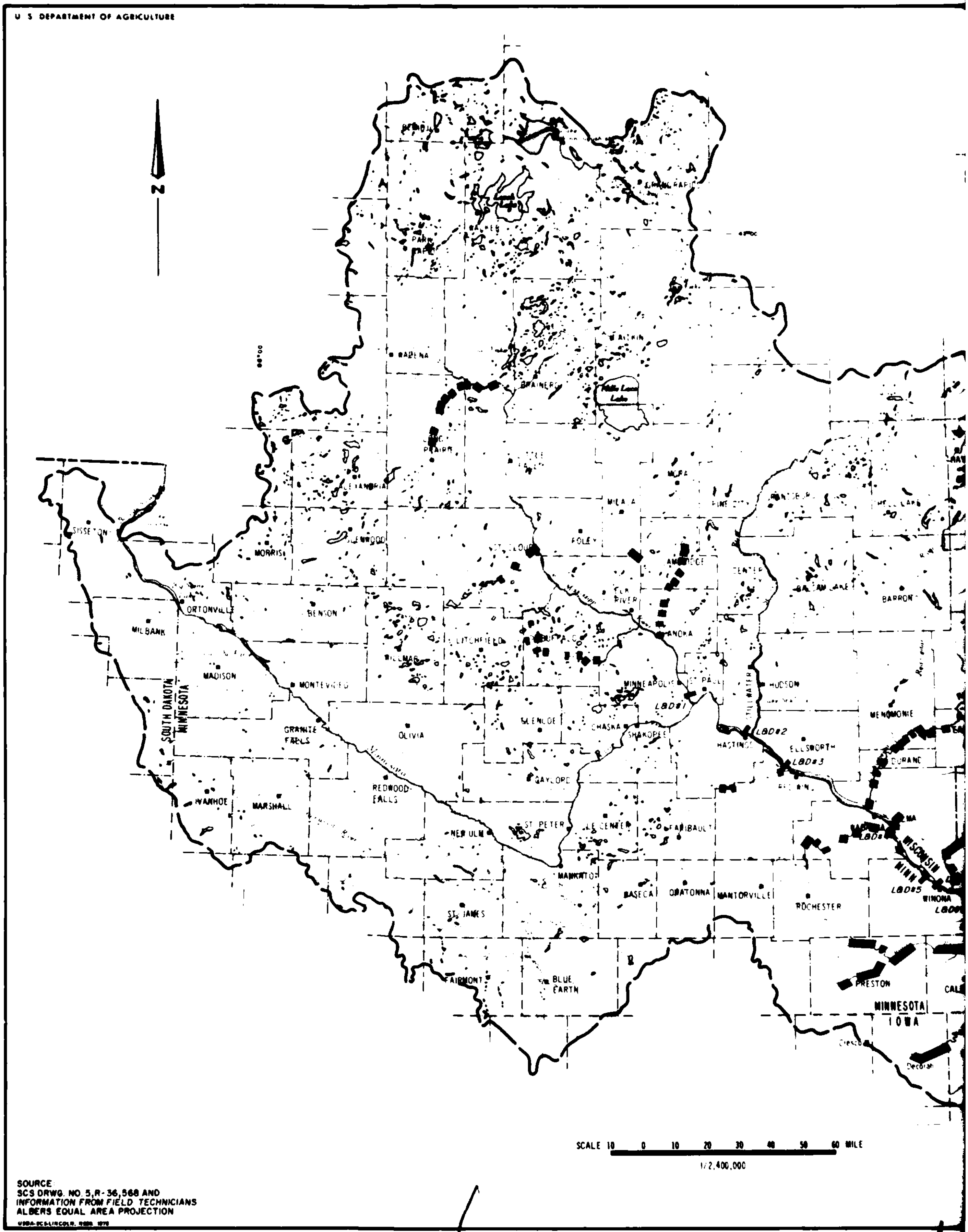
Streambank erosion in tributaries is responsible for most of the coarse material that deposits in the river channel. However, sheet and rill erosion on upland cropland areas is responsible for most of the finer sediments which are deposited in the backwater areas.

Before detailed studies of the quantity of erosion could be carried out, it was necessary to determine the geographic area which was responsible for the bulk of the fine sediment. It was also necessary to locate those areas on tributary streams which were responsible for the bulk of the sand deposited in the river channel.

SOURCE OF COARSE SEDIMENTS

The sand source map on page 88 was produced by mapping critical streambank erosion areas that were identified in a streambank erosion survey prepared by the Corps of Engineers. The erosion sites were identified by an on-the-ground survey of the principal tributaries in the area. Streambank erosion areas that were in drainage areas above sediment trapping reservoirs or lakes were excluded from the map.

Streambank erosion control alternatives on the Chippewa River - the highest sand contributor to the Mississippi River in the GREAT I area - are discussed in Chapter IV.



U S DEPARTMENT OF AGRICULTURE
N
BADENA
BRAINERD
Mille Lacs Lake
AITKIN
ALEXANDRIA
GLENWOOD
MORRIS
SISSETON
ORTONVILLE
MILBANK
BENSON
LITCHFIELD
WILLMAR
MADISON
MONTEVIDEO
SOUTH DAKOTA
MINNESOTA
GRANITE FALLS
OLIVIA
IVANHOE
MARSHALL
REDWOOD FALLS
NEW ULM
ST PETER
MANKATO
ST JAMES
FAIRMONT
BLUE EARTH
FOLEY
MILACA
PINE CITY
ANOKA
ELK RIVER
MINNEAPOLIS
ST PAUL
CHASKA
SHAKOPEE
GLENCOE
GAYLORD
LE CENTER
FARIBAULT
WASECA
OWATONNA
MANTORVILLE
ROCHESTER
HASTINGS
STILLWATER
HUDSON
ELLSWORTH
MENOMONIE
DURAND
BARRON
BALSAM LAKE
LBD#1
LBD#2
LBD#3
LBD#5
WINONA
WISCONSIN
MINN
PRESTON
MINNESOTA
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SCALE 10 0 10 20 30 40 50 60 MILE
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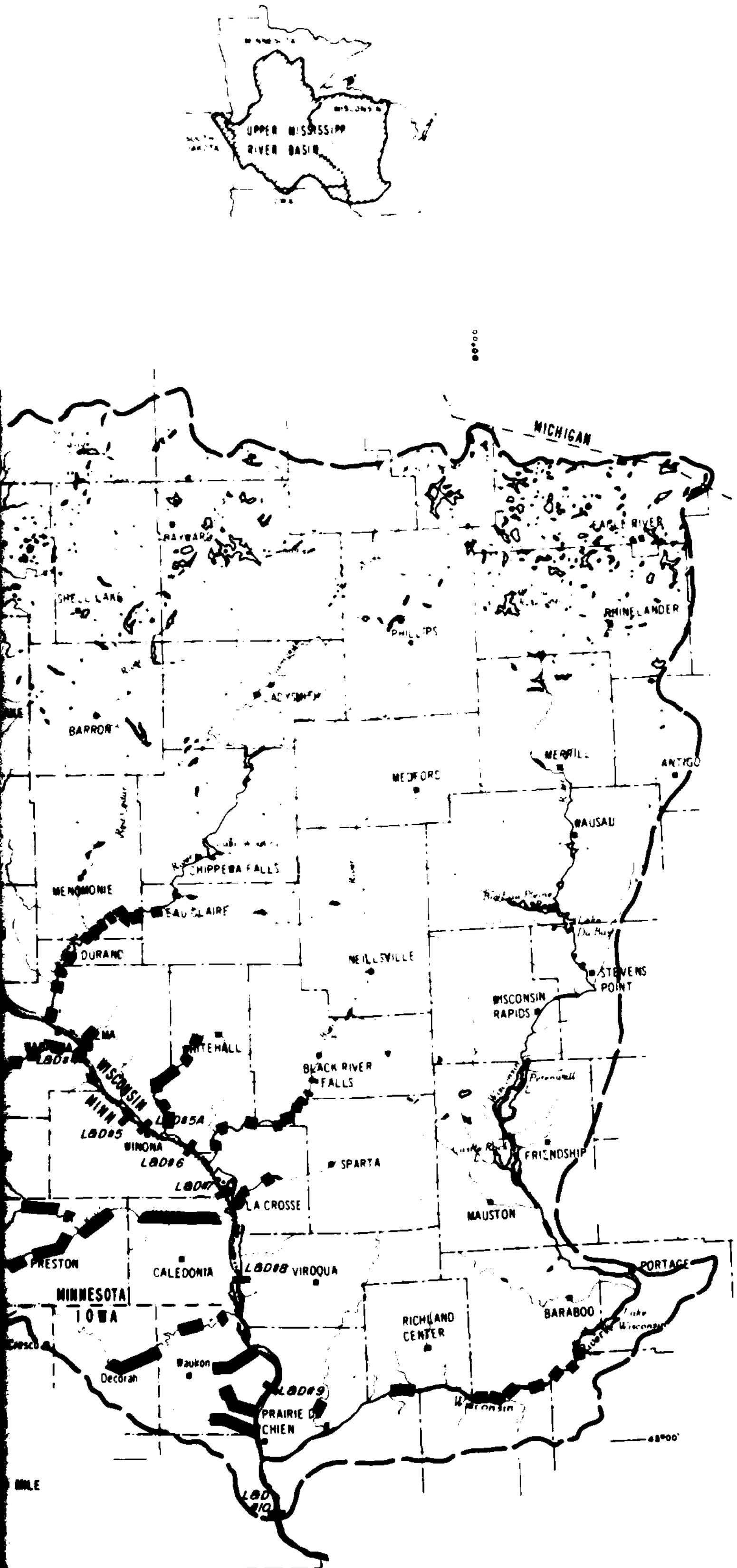
INFORMATION FROM FIELD TECHNICIANS
ALBERS EQUAL AREA PROJECTION



LEGEND

- NEGLIGIBLE
- MODERATE
- SEVERE

SAND SOURCE MAP

GREAT I

UPPER MISSISSIPPI RIVER BASIN

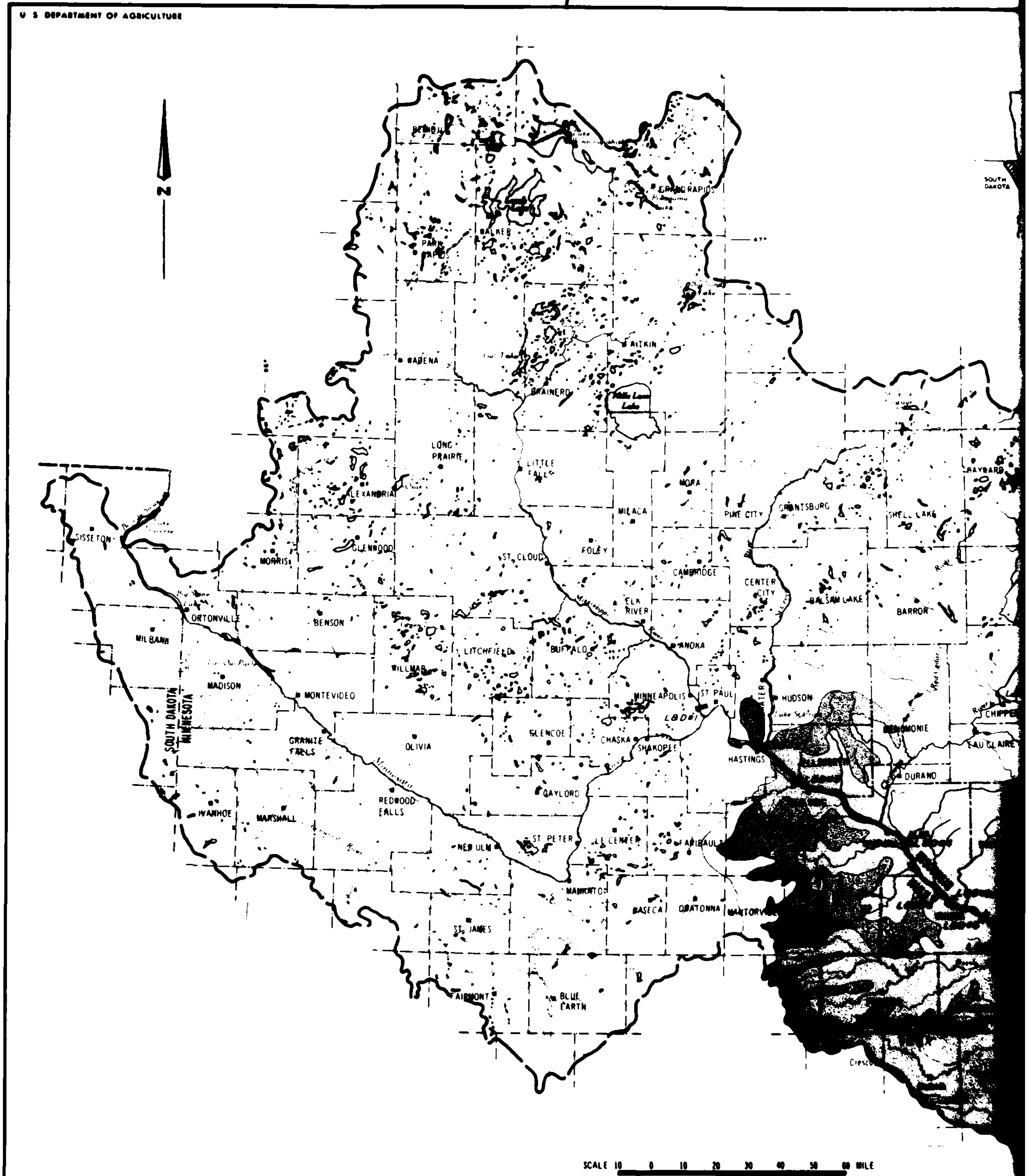
IOWA, MINNESOTA, SOUTH DAKOTA AND WISCONSIN

11-21-77
5,S-36,590

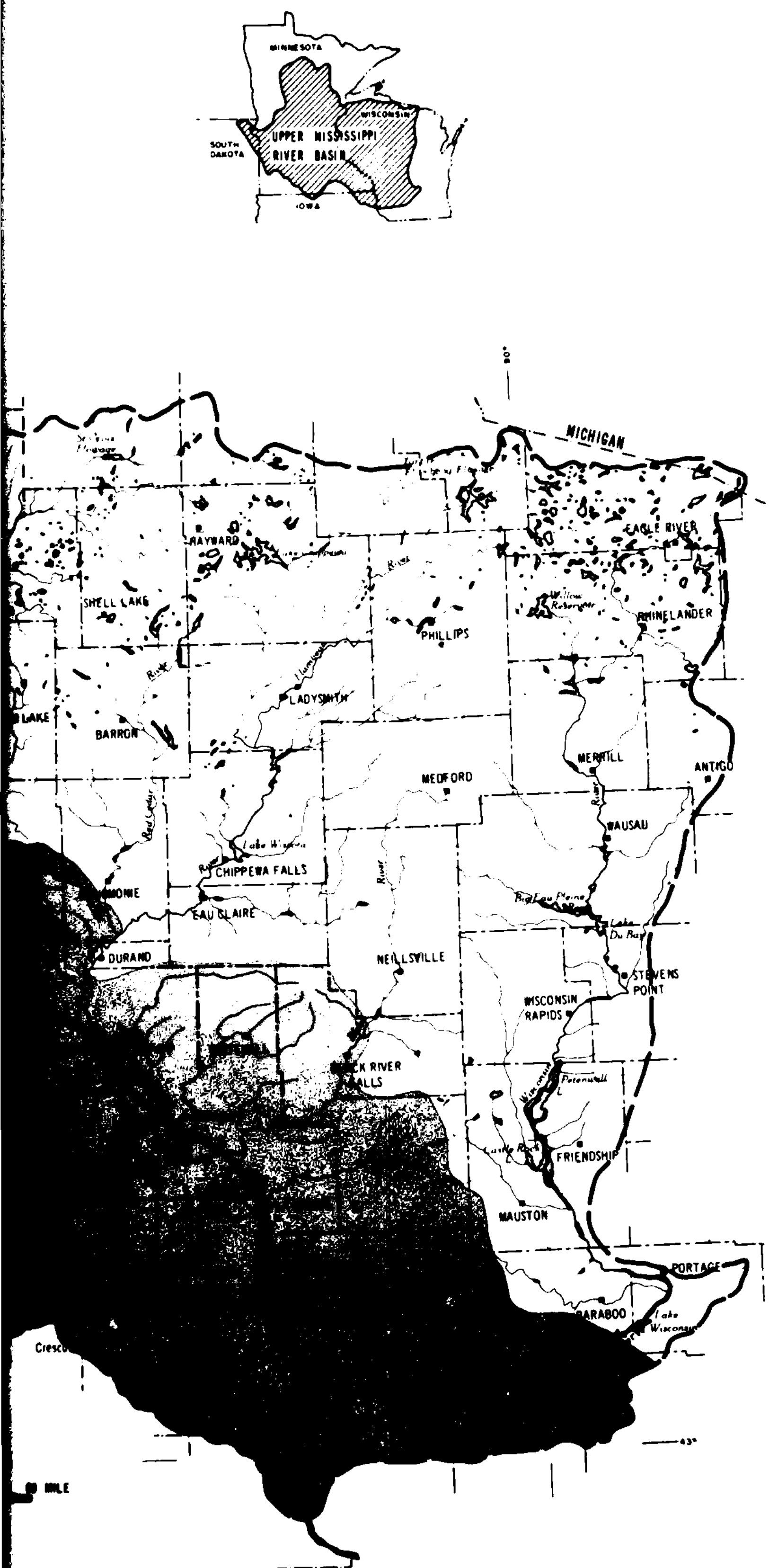
1 2

SOURCE OF FINE SEDIMENTS

The following map showing sediment sources was prepared by the work group using generalized soils maps and a knowledge of geology of the region. The critical sediment source area (colored area) depicting the sources of fine sediment does not incorporate the entire drainage area of GREAT I. The reason for this was that the critical sediment source area would not include drainage areas above lakes and reservoirs which serve as sediment traps. Other boundary areas were determined by the geologic characteristics of the region and the vegetative cover in portions of the GREAT I drainage area.



SOURCE
SCS DRAWING 5,R-36,568 AND
INFORMATION FROM FIELD TECHNICIANS
ALBERS EQUAL AREA PROJECTION



SOURCE OF SILT AND CLAY SEDIMENTS
EROSION HAZARD

- SEVERE
- SERIOUS
- MODERATE
- SLIGHT TO NONE

GREAT 1
SEDIMENT SOURCE MAP
UPPER MISSISSIPPI RIVER BASIN
IOWA, MINNESOTA, SOUTH DAKOTA AND WISCONSIN

11-4-77
5,S-36,578

LAND USE AND EROSION CONTROL

Once the principal fine sediment source area was delineated, a detailed study of the erosion and sediment sources to the Mississippi River corridor could be undertaken. The basis for the erosion study in the critical sediment source area was the "1967 Soil and Water Conservation Needs Inventory" prepared by the Soil Conservation Service in cooperation with other agencies of the Department of Agriculture, Department of the Interior, and State of Minnesota. The inventory was a comprehensive survey of the status of soil and water conservation in the United States. Data were collected on land use, the status of conservation land treatment by land use, and the type of conservation practices that would be needed to adequately protect those areas which did not have adequate conservation practices installed. The work group decided that the inventory would form the basis for an update of soil and water conservation needs in the identified critical sediment source area. Questionnaires were mailed to the Soil Conservation Service's district conservationists in each of the counties in the identified sediment source area. The district conservationists were asked to update the information. They reported on changes in land use which had occurred since 1967 and projected land use changes for 1985 and 2000. Updated values for land adequately protected and land needing protection from soil erosion were provided and projected for 1985 and 2000. In addition to determining acreage by land use and status of conservation, the district conservationists produced an estimate of the average amount of erosion occurring for each land use both for adequately protected land and land needing protection. This information was used as the basis for estimating the amounts of gross soil erosion and costs of erosion control programs.

The following table shows a breakdown of the land which is in inventoried and noninventoried uses. Inventoried uses are those land uses which are predominantly agricultural. Noninventoried acreages are urban and built-up areas, Federal lands which are not in cropland, and small water areas. As shown in the table, the GREAT I sediment source area is predominantly inventoried land uses. An increase in the built-up and urban area is projected. However, this category is still a relatively small percentage of the total land use.

Noninventoried and inventoried land areas (acres)

Year	Noninventoried area: Federal non-crop	Noninventoried area: Built-up urban	Noninventoried area: Small water areas	Noninventoried area: Total	Inventoried area	Total
1975	161,000	383,000	28,000	572,000	8,354,000	8,926,000
1985	161,000	416,000	29,000	606,000	8,320,000	8,926,000
2000	162,000	457,000	30,000	649,000	8,276,000	8,925,000

The following table breaks down the land use of the inventoried acreages. Of inventoried land, cropland makes up the majority of the land comprising approximately 52 percent. Forest land makes up approximately 29 percent of the area. The sediment source area also includes a large acreage of pastureland - approximately 15 percent of the total land use. Use of inventoried land in the sediment source area for GREAT I is projected to remain relatively stable through the year 2000. Small changes will occur in other land uses such as roads, farmsteads, feedlots, ditch banks, hedgerows, and fences.

Land use in inventoried areas (acres)

Year	Land use				
	Cropland	Pasture	Forest land	Other	Total
1975	4,358,000	1,211,000	2,419,000	366,000	8,084,000
1985	4,356,000	1,178,000	2,418,000	368,000	8,320,000
2000	4,333,000	1,146,000	2,422,000	375,000	8,276,000

The following table indicates the principal types of land treatment that would be required to protect cropland needing land treatment. The land treatment need for most of the cropland is strip-cropping, terraces, and diversions. Except for permanent cover, this type of protection is the most intensive and expensive. The type of land which would require strip-cropping, terracing, or diversions would be sloping land in row crop rotations.

Conservation treatment needs, cropland in tillage rotation (acres)

Year	Treatment adequate, irrigated and non-irrigated	Nonirrigated cropland						Irrigated cropland, water management	Total tillage in rotation
		Residue and annual cover	Sod in rotation	Contouring only	Strip-crop, terracing, diversion	Permanent cover	Drainage		
1975	1,867,000	241,000	196,000	126,000	1,383,000	248,000	231,000	7,000	4,299,000
1985	2,117,000	213,000	171,000	115,000	1,265,000	214,000	189,000	11,000	4,295,000
2000	2,472,000	168,000	150,000	99,000	1,070,000	174,000	122,000	14,000	4,269,000

Erosion by land capability class is shown in the following table. The land capability classes reflect the relative erosion hazard on the land. Generally speaking, Class IIe land is land with a 2- to 6-percent slope; Class IIIe land, a 6- to 12-percent slope; Class IVe land, a 12- to 18-percent slope; Class VIe land, an 18- to 25-percent slope; and Class VIIe land, greater than a 25-percent slope. While the erosion rates per acre are very high for the Class VIe and VIIe land, the relatively small amount of these classes in cropland makes protection for them a lower priority concern. The primary emphasis in land treatment should be on the Class IIe, IIIe, and IVe land, which represents the bulk of the cropland needing treatment for erosion. Class IIe, IIIe, and IVe land also represents the land which is most feasible to protect. Class VIe and VIIe cropland needing protection is land which should not be in cropland. Therefore, the most feasible treatment would be a return to permanent cover.

Cropland in tillage rotation by class/subclass, 1975

Capability class	Acres	Land adequately protected: Acres	Tons per acre per year	Tons per year	Land needing protection: Acres	Tons per acre per year	Tons per year	Total tons per year
I	200,000	145,000	1.9	270,000	55,000	4.7	259,000	529,000
e								
II	1,055,000	434,000	3.0	1,315,000	621,000	7.2	4,453,000	5,768,000
III	1,114,000	453,000	3.6	1,649,000	661,000	10.4	6,895,000	8,544,000
IV	655,000	308,000	3.7	1,128,000	347,000	9.3	3,224,000	4,352,000
VI	234,000	88,000	3.8	336,000	146,000	11.0	1,603,000	1,939,000
VII	67,000	25,000	4.2	105,000	42,000	11.6	488,000	593,000
Total e	3,125,000	1,308,000	3.5	4,533,000	1,817,000	9.2	16,663,000	21,196,000
s	446,000	207,000	2.1	433,000	239,000	4.5	1,074,000	1,507,000
w	528,000	207,000	1.2	245,000	321,000	2.4	780,000	1,025,000
Total	4,299,000	1,867,000	2.9	5,481,000	2,432,000	7.7	18,776,000	24,257,000

Erosion prevention and land protection needs by land use for 1975, 1985, and the year 2000 are given in the following table. While the bulk of the sediment is coming from cropland needing protection, a significant amount of sediment is coming from pastureland and forest land. These land uses, if properly managed, should be contributing very small amounts of sediment. The primary treatment need is proper management. Pastureland which is grazed in a rotation and managed for maximum pastureland production will produce minimal (less than 1 ton per acre per year) erosion. Forest land properly managed, likewise, should produce minimal (less than 1 ton per acre per year) erosion. One solution would be to exclude livestock from forest areas. Forest land produces relatively little grazing value for livestock. However, it is expensive to fence forest from other pastureland. The farmer realizes no direct economic benefit. Proper incentives could be used to provide livestock exclusion from forest land and thereby reduce erosion to a minimal level. Other lands needing protection are roadsides and ditch banks. These areas often produce very high rates of erosion on a per-acre basis. In general, the costs of protecting this land would be extremely high on a per-acre basis. Therefore, the money might better be used on other lands where the erosion reduction per dollar spent would be much greater. First priority should be given to cropland, pastureland, and forest land needing protection.

Erosion prevention and land protection needs by land use

Year	Cropland LAP(1)	Cropland LNP(2)	Other cropland LAP	Other cropland LNP	Pastureland LAP	Pastureland LNP	Forest land LAP	Forest land LNP	Other land LAP	Other land LNP	Total LAP	Total LNP	Total
1975													
Acres	1,867,000	2,432,000	30,000	29,000	573,000	638,000	1,143,000	1,276,000	236,000	130,000	3,849,000	4,505,000	8,354,000
Tons per acre per year	2.9	7.7	2.1	7.9	1.9	5.6	1.5	4.8	2.4	14.1	2.3	6.8	4.7
Tons	5,481,000	18,776,000	62,000	228,000	1,086,000	3,543,000	1,765,000	6,097,000	576,000	1,835,000	8,970,000	30,479,000	39,449,000
1985													
Acres	2,117,000	178,000	32,000	29,000	598,000	580,000	1,197,000	1,221,000	244,000	124,000	4,188,000	4,132,000	8,320,000
Tons per acre per year	2.9	7.7	2.0	7.9	1.9	5.5	1.5	4.8	2.4	14.1	2.4	6.7	4.5
Tons	6,224,000	16,815,000	65,000	230,000	1,134,000	3,211,000	1,850,000	5,826,000	593,000	1,753,000	9,866,000	27,835,000	37,701,000
2000													
Acres	2,472,000	1,797,000	32,000	32,000	625,000	521,000	1,277,000	1,145,000	257,000	118,000	4,663,000	3,613,000	8,276,000
Tons per acre per year	3.0	7.7	2.1	7.7	1.9	5.5	1.5	4.8	2.4	14.1	2.4	6.7	4.2
Tons	7,312,000	13,865,000	67,000	245,000	1,189,000	2,867,000	1,973,000	5,462,000	624,000	1,657,000	11,165,000	24,096,000	35,261,000

(1) Land adequately protected from excess erosion.
(2) Land needing protection to reduce erosion to a level which would allow for the long-term survival of the soil resource base.

The following table shows the projected levels and costs of the ongoing land treatment program. This is the program that would take place with current funding levels and technology. Approximately 46 percent of the land in the critical sediment source area is adequately protected within Soil Conservation Service standards. The level of land adequately protected would increase to approximately 55 percent by 1985 and increase only slightly to the year 2000. The reason for this slower rate of progress from 1985 to 2000 is the amount of funding and technical assistance which would be tied up with renewal of the existing practices. It has been observed before that land treatment practices and land treatment structures are relatively short-lived. Renewal and replacement are necessary on a relatively frequent basis. With this increased level of protection, annual soil loss would decrease from the current level of about 39½ million tons to approximately 35 million tons by 2000. During this time period, some $50 million would be spent by 1985 to install land treatment measures which would achieve the 54.6-percent level of land treatment projected. By the year 2000, some $61 million would be spent in installing conservation practices. The table indicates that $8 million in technical assistance would be necessary to achieve the 54.6-percent level of land adequately protected and almost $10 million in technical assistance would be required by the year 2000 to achieve the 54.6-percent level of adequate protection. The last column in the table indicates the annual cost of maintaining conservation practices once installed. This is the cost of operation and maintenance and a sinking fund which would be required to replace or renew these practices. The annual cost of maintaining the level of land treatment projected for year 2000 would be $30.5 million. This increasingly high level of operation, maintenance, and replacement costs explains in part why the increase in the percentage of land adequately protected would taper off after 1985.

Cost of ongoing land treatment program[1]

Year	Land use	Total acres	Land adequately protected: Acres	Land adequately protected: Per-cent	Annual soil loss (tons)	Acres protected above 1975 base	Cost: Installation	Cost: Technical assistance	Cost: Total	Cost: Annual operation and maintenance
1975	Cropland	4,299,000	1,867,000	43.4	24,257,000					
	Other	4,055,000	1,982,000	48.9	15,192,000					
	Total	8,354,000	3,849,000	46.1	39,449,000					$25,058,000
1985	Cropland	4,295,000	2,117,000	49.3	23,039,000	250,000	$19,950,000			
	Other	4,025,000	2,426,000	60.3	14,662,000	444,000	29,748,000			
	Total	8,320,000	4,543,000	54.6	37,701,000	694,000	49,698,000	$8,328,000	$58,026,000	29,490,000
2000	Cropland	4,269,000	2,472,000	57.9	21,177,000	605,000	47,190,000			
	Other	4,007,000	2,191,000	54.7	14,084,000	209,000	14,003,000			
	Total	8,276,000	4,663,000	56.3	35,261,000	814,000	61,193,000	9,768,000	70,961,000	30,565,000

(1) All costs represent the cost of going from the 1975 level to the 1985 or 2000 level. Therefore, the cost of going from the 1985 to 2000 level would be cost for 2000 minus the cost for 1985.

EXISTING CONTROL ALTERNATIVES

The costs and benefits of three different levels of accelerated land treatment are presented in the following table.

Costs for various levels of land treatment, 1975 base

Plan	Land use	Total acres	Land adequately protected: Acres	Land adequately protected: Percent	Annual soil loss (tons)	Acres protected above 1975 base	Cost: Installation	Cost: Technical assistance	Cost: Total	Annual operation and maintenance
A	Cropland	4,299,000	3,091,000	71.9	18,695,000	1,224,000	$95,472,000	$14,688,000	$110,160,000	
	Other	4,055,000	2,756,000	68.0	12,190,000	774,000	51,858,000	9,288,000	61,146,000	
	Total	8,354,000	5,847,000	70.0	30,885,000	1,998,000	147,330,000	23,976,000	171,306,000	$38,318,000
B	Cropland	4,299,000	3,607,000	83.9	16,219,000	1,740,000	135,720,000	20,880,000	156,600,000	
	Other	4,055,000	3,076,000	75.9	10,945,000	1,094,000	73,298,000	13,128,000	86,426,000	
	Total	8,354,000	6,683,000	80.0	27,164,000	2,834,000	209,018,000	34,008,000	243,026,000	43,869,000
C	Cropland	4,299,000	4,299,000	100.0	12,897,000	2,432,000	189,696,000	29,184,000	218,880,000	
	Other	4,055,000	4,055,000	100.0	7,137,000	2,073,000	138,891,000	24,876,000	163,767,000	
	Total	8,354,000	8,354,000	100.0	20,034,000	4,505,000	328,587,000	54,060,000	382,647,000	54,631,000

Plan A, a 70-percent level of land adequately protected, is estimated to be the level of land treatment that would be practical if funding were adequate to meet all of the requests for technical assistance and cost sharing to apply current land treatment practices. Plan A would reduce soil loss from a level of 39.5 million tons to approximately 31 million tons. The cost of installing the practices necessary to achieve the 70-percent level of land adequately protected would be $171 million. In addition, approximately $38 million would be needed annually to maintain the 70-percent level of land adequately protected.

Plan B, an 80-percent level of land adequately protected, is estimated to be the maximum level of land adequately protected possible with mandatory soil loss restrictions. Plan B would reduce the soil loss from 39.5 million tons to 27 million tons. Plan B would cost $243 million to implement and $44 million annually to maintain this level of land treatment.

Plan C, a 100-percent level of land adequately protected, is presented merely as a reference point. This condition is not likely to occur anytime in the foreseeable future. If this condition were possible, soil loss would be cut almost in half at a cost of $383 million with an annual cost of $55 million to maintain this level of land treatment.

With current land treatment practices the maximum possible soil loss reduction is approximately 50 percent. The relatively short life expectancy of some of the pools and the high cost of such a program protecting 100 percent of the land raises serious questions as to the total adequacy of current land treatment practices as a means of increasing water quality and reducing sedimentation in the Mississippi River corridor.

NEW CONTROL ALTERNATIVES

Conservation tillage systems which could reduce sediment yields and erosion rates to a level that would allow the long-term survival of the Mississippi River backwaters and Lake Pepin are being tried at the Hiawatha Valley Demonstration Farm in Winona County, Minnesota. The purpose of the farm is to demonstrate old and new methods of farming directed toward improved soil and water conservation. Many of the tillage practices demonstrated have been limited primarily to small plots and experiment stations. Tillage practices demonstrated included no till, till plant, and conventional mold board plowing. The first year's operation of the demonstration farm (1978) brought to light many of the problems of management, chemical application, and timing of field operations and chemical applications. One of the most striking things in the first year's data is that yields on no till and till plant systems compare quite favorably with yields on conventionally tilled ground. Many of th plots are located in an area where erosion on conventionally tilled land is 30 to 40 tons per acre. Erosion on land in no till cultivation systems is reduced from 30 to 40 tons per acre to 3 to 5 tons per acre. Yet, the yields on the no till land are only slightly less in many of the plots than the yields on the conventionally tilled ground. It should be pointed out that the demonstration farm is a "demonstration farm" and not an "experiment farm." The demonstrations were not carefully controlled scientifically. However, the demonstration plots do point out the enormous potential in no till and conservation tillage farming as ways to reduce erosion in critically eroding areas (Hansgen, 1978).

CONCLUSIONS

Further work needs to be done in the GREAT I critical sediment source area to fully determine the potential of no till and conservation tillage farming as ways to save the backwaters of the river. This study should direct itself toward determining:

1. The potential reduction in soil loss with the use of conservation tillage.

2. Changes in the farming practices which would be required by a change to conservation tillage farming. This would include studies of types of chemicals, rates of application, timing of application, changes in management practices, changes in types of machinery and equipment, and other adaptations which would be required by a conversion to conservation tillage farming.

3. Changes in yields and net returns which would result in conversion to conservation tillage farming.

4. Types and amounts of economic incentives which would be needed to induce widespread conversion to conservation tillage.

The ultimate method to curtail upland erosion in the critical sediment source area for GREAT I is believed to be a combination of the continued application of the traditional soil conservation practices and the application of new soil conservation practices oriented specifically toward the reduction of soil loss and the improvement of water quality. On the basis of the work done by the Hiawatha Valley Demonstration Farm, it appears that enormous potential exists to reduce sediment and improve water quality using conservation tillage farming. If it is demonstrated that conservation tillage farming is a viable means of reducing sediment and that it does reduce yields, a subsidy might be an appropriate way to induce farmers to switch to conservation tillage farming.

CHAPTER VII

CONCLUSIONS

The SEWG has studied the sedimentation problems which threaten the Upper Mississippi River as a valuable environmental, economic, and recreational resource. On the basis of studies conducted to determine the extent of sedimentation, the time constraints under which corrective action must be taken, and the consequences of the no action alternative, the work group has reached a series of conclusions which clearly identify a real and urgent sedimentation problem and point out what measures can be taken to solve the problem. While the conclusions reached from these studies were not unexpected, the relative totality of the sedimentation dilemma throughout the river corridor and the immediacy of potential irreversible impacts were unforeseen.

FINE PARTICLE SEDIMENTATION

Accumulation of fine sediments in backwaters, low-flow pool areas, and isolated side channels has caused significant loss of productive aquatic habitat in the period since impoundment. The water in these areas is shallow. If sedimentation continues at its present rate, much of this valuable habitat acreage will be converted into semi-aquatic marshland within the next century. The Upper Mississippi River, known for its fish, wildlife, and habitat diversity, will not retain its present environmental value unless immediate remedial action is taken.

The source of fine sediment is upland erosion. Therefore, any attempt to reduce fine sedimentation in the river corridor must focus on more environmentally sound land use practices. The critical eroding areas are identified on the sediment source map on page 88. This area should be given top priority for action to prevent further habitat loss to fine sedimentation. This is the only hope for extending the existence of the Mississippi River pools and backwaters.

Evaluation of current agricultural land treatment programs indicates that land treatment is an important means of curtailing upland erosion. However, current practices alone are not enough to provide a long-term solution to the sedimentation problem in the river. Measures that have a greater potential for erosion reduction than those in widespread practice will be necessary to reduce sedimentation to a level that will ensure the long-term survival of the Upper Mississippi River backwaters.

Side channel alterations, diking flow manipulation, or other structural modifications within the river corridor may be practical for preventing further decline of critical wildlife areas. Such projects would not, however, be sufficient to solve the total fine sedimentation problem.

SAND SEDIMENTATION

A second problem of crucial concern is the accumulation of coarse sediment (sand). This sand must be periodically dredged to maintain the 9-foot navigation channel.

Sediment carrying capacity normally confines movement of coarse sediments to the bottom of the main channel. Thus, the problem originally is one of the economics of channel maintenance. These sediments create little disruption of biological activity along the bottom of the main channel. However, dredging and material placement seriously damage the more sensitive main channel border and adjacent backwaters.

Some of the problems caused by dredging accumulated sand sediments to maintain the channel are:

1. Loss of productive biological habitat at the main channel border and adjacent backwaters, side channels, and wetlands as a result of being covered by dredged material.

2. Turbidity and resuspension of sediment during dredging.

3. Habitat loss, side channel blockage, and potential reshoaling in the main channel caused by secondary movement of dredged material.

4. Secondary movement of dredged material that covers main channel border prime fish use areas (wing dams, snags, rocks, etc.).

5. Aesthetic degradation caused by sand piles.

The problems caused by sand accumulation in the river corridor can be alleviated by (1) control of sand erosion at the source, (2) more environmentally sound dredging and material placement techniques, and (3) in-channel protection measures. Streambank erosion control measures should be evaluated in terms of both economic and environmental benefits. Even when a measure cannot be justified on economics alone, consideration should be given to implementation when considerable environmental benefits can be expected.

SAND SEDIMENT EROSION CONTROL

The source of sand entering the river system is primarily bank erosion on tributary streams. Costs for bank stabilization projects are extremely high and often prohibitive. An exception is the Chippewa River which is the largest sand source in the GREAT I area. Approximately 360,000 tons of sand are dredged annually from a 6-mile area immediately below the confluence of the Chippewa and Mississippi Rivers. Significant reductions in dredging requirements (and related maintenance cost savings) alone make bank control at strategic locations on the Chippewa River feasible. Implementation of the most feasible control measures (to be determined by the Corps Chippewa River Basin Feasibility Study) on other critical tributaries (identified on the sand source map on page 70) may be practical and cost effective.

ENVIRONMENTALLY SOUND DREDGING PROGRAM

Although bank protection efforts to reduce sand flow into the Mississippi River are possible in many cases, cost constraints prohibit stabilization at all sand sources. Therefore, while bank protection measures could reduce dredging requirements, they will not replace the need to maintain the 9-foot channel. The Material and Equipment Needs Work Group is reviewing dredging equipment and capabilities and new designs to identify options that will reduce the impacts of channel maintenance on the environment.

Ideally, all dredged material should be placed out of the river's floodplain. This would eliminate direct placement on riverine habitat and prevent secondary movement of dredged material and its related impacts on the environment. Out-of-floodplain placement is not always economically acceptable, however, because long distance placement expenses exceed the Corps operation and maintenance budget. Until long distance placement can be accomplished with new dredging equipment capabilities in a cost effective manner, placement site selection will compromise dredging costs and potential environmental damage. GREAT has accomplished this balance in the Channel Maintenance Appendix and through the interagency on-site inspection team. The inspection team has identified the most environmentally and economically acceptable placement sites and ensures compliance with State and Federal placement and water quality regulations.

IN-CHANNEL PROTECTION MEASURES

In-channel placement will continue until long distance capability is obtained. Every effort should be made to stabilize dredged material piles to prevent secondary movement. Vegetation on sandpiles would protect from flood flows and would prompt succession to a more natural and aesthetically acceptable habitat.

The Corps ongoing shoreline protection program has benefited the environment by preventing tow propwash and flood flows from eroding channel banks, thereby minimizing additional sediment input into the system. An extensive inventory and evaluation list prepared by several GREAT work groups (including the SEWG) has identified areas that need shoreline protection. The Corps should continue its shoreline protection program using the priority list prepared by GREAT.

RELATIONSHIP BETWEEN SAND AND FINE SEDIMENTATION

Although the accumulations of sand and fine sediments have been presented as separate problems, there is an unmistakable cause and effect relationship between them. The most obvious impact from sand accumulation is the habitat loss as a result of dredged material disposal. However, the secondary movement of this sand can potentially intensify fine sedimentation in backwaters and off-channel areas. When erosion of dredged material induces shoaling of coarse sediment at the mouth of a side channel, flow loss through companion backwater areas allows fine suspended sediment to settle out and thus accelerates fine sedimentation. Maintained flow through backwaters is also essential as a source of oxygen. Proper site selection and stabilization is of extreme importance for minimizing backwater sedimentation rates, habitat loss, and biological productivity.

NEED FOR EXPANDED DATA COLLECTION

Identification and monitoring of tributaries in the GREAT I area have been used to determine which tributaries are producing high sediment yields to the Mississippi River. Data gathering has been useful for recommending control for those streams with the highest sediment output. Attachment B to this report contains an evaluation of sediment data collected during the GREAT I study. This report was prepared under contract by Colorado State University.

Stream sediment monitoring and analysis are ongoing programs of the U.S. Geological Survey and the St. Paul District, Corps of Engineers. The SEWG, in cooperation with the Corps, has initiated monitoring studies of the Chippewa River to determine coarse sediment yield. This information will be helpful as base-line data to determine the sediment yield reductions and correlations caused by the Corps Chippewa River erosion control demonstration project. Establishment of monitoring stations on other identified tributaries or on tributaries previously not inventoried for critical yield analysis would help determine where control measures should be implemented and provide base-line data for analyzing the success of new sediment control systems.

CHAPTER VIII

SEDIMENT AND EROSION WORK GROUP RECOMMENDATIONS

RECOMMENDATION 1

Recommendation

Application of existing upland erosion control practices should be accelerated to the maximum extent possible. The critical sediment source areas identified on the "GREAT I Sediment Source Map" should have top priority for funding and implementation in the GREAT I drainage area.

Justification

The principal cause of the loss of fish and wildlife habitat in the Upper Mississippi River backwaters is the accumulation of fine sediments eroded from upland agricultural areas. This conclusion is based on an evaluation of the results of the following work group studies:

1. Particle size analysis of geologic borings.

2. Re-sounding of Lake Pepin.

3. Cs-137 sediment dating process.

4. Aquatic habitat comparison study.

Acceleration of the application of existing land treatment practices would result in a decrease in gross erosion from agricultural areas and in the ultimate deposition of this eroded material in the river system backwaters. The land treatment analysis indicates that an

80-percent level of land adequately treated would decrease upland erosion by one-third. Presently, 46 percent of the land within critical sediment source area boundaries is adequately treated according to Soil Conservation Service standards.

Procedure

Implementation should be carried out under the authority of the Rural Clean Water Program.

RECOMMENDATION 2

Recommendation

A two-phase study should be conducted in the GREAT I critical sediment source area to determine the feasibility of large-scale use of conservation tillage farming systems as a means of substantially reducing the sediment yield to the Mississippi River. In addition, the phase 1 portion of that study (as outlined below) would include feasibility analysis of additional soil conservation alternatives identified by members of an interagency river management team.

Phase 1 of the study would be designed to determine:

1. Potential reduction in soil loss.

2. Changes in farming practices that would be required. This would include studies of types of chemicals, rates of application, timing of applications, changes in management practices, changes in types of machinery and equipment and other adaptations which would be required by a conversion to conservation tillage farming or other soil conservation alternatives.

3. Changes in yields and net returns that would result from implementing conservation tillage farming or other alternative practices.

4. Types and amounts of economic incentives that would be needed to induce a widespread conversion to conservation tillage or other alternative soil conservation practices.

Phase 2 of the study would be an on-the-ground demonstration project in a watershed area identified as being a significant sediment source to the Mississippi River. The demonstration watershed would be closely monitored to determine the benefits of alternative land treatment practices and conservation tillage farming. Gaging stations would be established to monitor sediment delivery during the project. A comparison watershed would be monitored to determine existing or baseline conditions.

Justification

The Sediment and Erosion Work Group has determined that the life expectancy of several of the pools is very short - 50 to 250 years. The maximum erosion reduction theoretically possible with current soil conservation practices is 50 percent. Therefore, to preserve the pools for the long run, it will be necessary to develop soil conservation technology that will reduce erosion above and beyond the limits of the current program.

Procedure

Phase 1 should be conducted by the U.S. Department of Agriculture's Science and Education Administration under the guidance of the Soil Conservation Service. The demonstration project should be implemented

by the local soil and water conservation district, watershed district, or other local sponsor. The project funding and direction should be provided by GREAT, an interagency, interdisciplinary coordination team. Technical assistance would be furnished by the Soil Conservation Service.

RECOMMENDATION 3

Recommendation

The Corps of Engineers should continue its program of the evaluation of the alternatives for sediment control on the Chippewa River. The two alternatives selected for further study in the Chippewa River basin preliminary feasibility report should be implemented if they are found to be feasible.

Justification

Bank erosion from the Chippewa River and resulting deposition of coarse sand into the Mississippi River has resulted in loss of floodplain land and increased channel maintenance requirements. Implementation of feasible bank erosion control measures would decrease erosion and its related impacts on the Mississippi River corridor.

Procedure

The Corps of Engineers should continue the Chippewa River basin study under its present authorities.

RECOMMENDATION 4

Recommendation

The Corps of Engineers should continue restoring and establishing shoreline protection on a yearly basis following the design and priority list prepared cooperatively by the Sediment and Erosion, Fish and Wildlife, and the Dredging Requirements Work Groups until completion.

Justification

Shoreline erosion within the river corridor increases the sediment load to the Upper Mississippi River. This accelerated sedimentation destroys fish and wildlife habitat and increases navigation channel maintenance requirements. Sedimentation will be slowed if shoreline protection measures are implemented.

Procedure

The Corps should continue restoring and establishing shoreline protection structures using existing authority and funding (River and Harbor Acts).

RECOMMENDATION 5

Recommendation

A follow-up to the Corps of Engineers "Streambank Erosion Site Inventory" should be conducted cooperatively between the Soil Conservation Service and the Corps of Engineers to determine and classify streambank erosion sites not previously identified. Alternatives for bank erosion control should be developed and analyzed for economic and environmental impacts. Implementation authority and cost-sharing criteria should be developed so that control alternatives can be accomplished.

Justification

Streambank erosion from tributaries has been identified as the principal source of coarse sediments entering the Mississippi River. Applied control measures on identified high coarse sediment contributing tributaries will reduce channel maintenance requirements and the potential secondary impacts on fish and wildlife habitat associated with dredged material disposal.

Procedure

The follow-up phase of this recommendation should be conducted cooperatively by the Soil Conservation Service and the Corps of Engineers. Program development should be conducted by those two agencies in consultation with GREAT.

RECOMMENDATION 6

Recommendation

Barren sand dredged material piles should be stabilized with vegetation.

Justification

While it is not felt that resuspended sand is a major source of coarse material requiring channel maintenance, every effort should be made to stabilize dredged material piles to avoid resuspension and damage to backwaters.

Procedure

The Corps of Engineers should adopt this policy as part of its standard operating procedures for channel maintenance under existing operation and maintenance authority.

RECOMMENDATION 7

Recommendation

Monitoring of sediment inflow from major tributaries should be continued. The U.S. Geological Survey should review all tributaries with GREAT to establish priorities for additional sediment sampling stations.

Justification

The existing monitoring programs of the Geological Survey have provided base-line information regarding tributary sediment contributions to the river corridor, as would newly established stations. These data will be useful for identifying priority watersheds for implementation of upland erosion control practices and streambank protection measures. Gaging station data should be used to determine site selection of the upland treatment demonstration project discussed in Recommendation 2.

Procedure

The Geological Survey should continue to expand its monitoring program under present authorities and in consultation with GREAT.

RECOMMENDATION 8

Recommendation

Diking of critical backwater areas threatened by sediment accumulation should be considered as an alternative protection measure. Water flow control structures should be provided, where appropriate, to ensure exchange of fresh water during normal flow periods to prevent seasonal fish kills. Design should fully consider potential impacts on flood elevations.

Justification

Examination of the Meyer data in areas where dikes and levees exist indicates that the diking of backwater areas is a workable means of preserving critical fish and wildlife areas. The extent of fine sedimentation in backwater areas immediately behind dikes was considerably less than the sedimentation in areas not protected by dikes.

Procedure

The Fish and Wildlife Service, in consultation with GREAT, should identify critical backwater areas which may benefit from diking construction. Construction operations should be done by the Corps under existing 9-foot channel operation and maintenance authority expanded to include fish and wildlife preservation and enhancement as project purposes.

AFTERWORD

The following illustrations were prepared during the course of the study but were not included in the final report:

1. 1895 contour map of Lake Pepin.

2. 1976 contour map of Lake Pepin.

3. Cesium 137 sediment dating location map.

4. Location of geological borings, Lake Pepin.

5. Geological borings in the bottom of Lake Pepin.

Information regarding these illustrations is available from the Soil Conservation Service, 200 Federal Building and U.S. Courthouse, 316 North Robert Street, St. Paul, Minnesota 55101.

GLOSSARY

Aquatic habitat - An environment conducive to the life and reproduction of water-based flora and fauna.

Chisel, disk, or rotary tillage - Seedbed preparation performed over the entire surface area without inversion of the soil. Tillage and planting may or may not be accomplished in the same operation. A protective cover of crop residues is left on the soil surface to reduce soil loss.

Clay - Soil particles less than 0.002 millimeter in diameter.

Conservation tillage - A form of noninversion tillage that retains protective amounts of residue mulch on the surface throughout the year. Conservation tillage includes no tillage, strip tillage, stubble mulching, and other types of noninversion tillage.

Contour farming - Conducting all tillage practices along the natural contours of the land.

Dike - A levee to confine or restrict the flow of water.

Diversion - An embankment constructed across the land slope (terrace) to divert water away from active gullies, eroding slopes, buildings, or critical areas.

Erosion - Detachment and removal of soil material by the forces of water, ice, wind, and gravity.

Fathometer - A device used to measure water depth.

Land adequately protected - Land with an erosion level low enough to allow for the long-term survival of the soil resource.

Land needing protection - Land requiring the use of conservation practices to reduce erosion to a level which will allow for the long-term survival of the soil resource.

Land treatment - Soil conservation practices designed to prevent erosion or enhance the land resource.

No-till, slot, or zero tillage - Seedbed preparation and planting completed in one operation. The only area disturbed is the planted seed row. A protective cover of crop residue is left on 90 percent of the surface to control erosion.

Residue and annual cover - The practice of leaving crop residues on the soil surface or the use of annual cover crops to control erosion.

Sand - Soil particles between 0.05 and 2.0 millimeters in diameter.

Sediment - Mineral or organic soil material which has been transported from its original location to another location by the action of wind, water, ice, or gravity.

Sediment density - The ratio of the weight of a given unit of sediment to its volume.

Silt - Soil particles between 0.002 and 0.05 millimeter in diameter.

Sod in rotation - The use of a sod crop in the cropping rotation to control erosion.

Spud - A grooved steel rod used to sample layers of sediment.

Strip-cropping - The practice of growing alternating types of crops in strips to control erosion. Contour strip-cropping is the alignment of these strips along the contour of the land.

Strip tillage - Seedbed preparation usually completed with a rotary type tiller, which mixes the residue and soil in the area to be planted. Tillage is limited to approximately one-third of the total row area. The untilled area (two-thirds) is left with a protective cover of crop residues to control erosion. Planting and tillage are usually one operation.

Terrace - An embankment constructed across the slope of the land. It is designed to interrupt the flow of water down the slope, thereby reducing erosion.

Till plant - Seedbed preparation and planting completed in one operation. The surface soils and residues are pushed from the old crop row into the row middles. Actual tillage only covers about one-third of the area. The remaining two-thirds of the surface area is covered with a protective cover of residue and loose soil.

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ATTACHMENT A

CORRESPONDENCE

ON

DRAFT SEDIMENT AND EROSION WORK GROUP APPENDIX

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WISCONSIN BOARD OF SOIL AND WATER CONSERVATION DISTRICTS	A-4

WE CAN'T ALL LIVE UPSTREAM

CCMI

Citizens for a Clean Mississippi, Inc.

Box 61 Pepin, Wisconsin 54759

July 3, 1979

Gary LePage, Chairman
Sediment & Erosion Control Work Group
Great Environmental Action Team
U.S. Soil Conservation Service
316 N. Robert
St. Paul, MN 55101

Dear Gary,

I had an opportunity to visit with both Jerry Hytry and Bill Rose in Madison on June 22, at which time I expressed my disappointment in their lack of cooperation with your work group in formulating the final appendix. Bill said he would call you the following Monday.

Having taken the time to review the May draft of the SEWG appendix and, despite my knowing the lateness of the hour, I would like to make the following comments.

We are pleased that the Wisconsin Conservation Districts have shown a positive interest, and that you have used the term "conservation tillage" rather than "no-till" in the new SEWG draft appendix.

The revised draft is greatly improved. It is well organized and written in a language that most people can understand; however, I still sense a lack of urgency and strong enough statements that will prompt Congress to give sediment and erosion control a top priority. We know how SCS funds have been limited for personnel, for travel, for RC&D projects, etc. In fact, our Congressman Al Baldus says SCS is not getting any more funds now than they received in the early '30's; thus, in view of the higher salaries and increased costs, the budget is not sufficient to get the field work done. It seems to us that this GREAT Report should provide the stimuli to get the monies necessary to make things roll.

The report very adequately provides proof of some of the existing problems and the possible cures, but it still is not likely to provoke immediate, positive action.

The significance of the maps to be included, such as the loss of aquatic habitat and Lake Pepin sedimentation, is now more adequately interpreted for the reader.

There is a question in my mind as to whether the report should infer that remedies are so cost-prohibitive. Who are we to judge? The time may well come when our soils will have to be preserved and our waters cleaned up, regardless of escalated costs.

As far as the experimental streambank projects on the Chippewa are concerned, we still maintain that the results are not apt to be applicable to many of the streams that carry silt and sand to the River. We are also disappointed that all streams that carry a bed-load to Lake Pepin are not identified, such as the Rush River, the Trimbelle River, Isabelle Creek, as well as dry runs such as at Maiden Rock. These streams may not have as much effect on the River as do the Chippewa, the Cannon or the Zumbro; but in that a whole chapter was included on Lake Pepin, the report should be more inclusive, especially when the contour maps show the results of their sedimentation effects. As I said at your meeting, recommendations must be made to document all the stretches of these tributaries that need streambank stabilization. We should recommend that demonstration projects be implemented on other streams besides the Chippewa. There may be other remedies that are less costly than rip-rapping. We know people on the Wisconsin River who have actually curtailed the loss of their property using old tires.

We believe the statement about the delta at the confluence of Bogus Creek and Lost Creek should be left in the report. The watershed developments above are operating effectively, but the lower streambanks are sorely in need of stabilization. Deer Lake continues to fill in and the muck still comes down to Bogus Point. We could show you a productive cornfield in the floodplain there, with topsoil brought down by Bogus Creek.

We were quite impressed with the contour maps of Lake Pepin, but you no doubt had adequate reason for omitting them from the new draft.

I have written for a copy of the Water Quality Work Group's appendix because your description of the sediment in Lake Pepin is not complete. The eutrophication is not mentioned, even though the EPA National Eutrophication Survey Report (1975) indicates that Lake Pepin has 11 times more phosphorus than it should have, according the the Vollenweider scale. The sources of phosphorus should be identified in some report. Lake Pepin is fouled with dead, stinking algae and the foam is unreal.

We agree that, except for periods of high flow, most organic material from the Twin Cities may be oxidized before it reaches Lake Pepin; but the fact remains that industrial wastes, such as PCB's, heavy metals and other toxic substances, are carried by small soil particles and do settle out in the lake, only to be re-suspended by the towboats. The overtone of the SEWG report tends to belittle the metro contamination of the water and the sediment. We maintain that it is a significant factor, and this was proved by expert testimony given at the 7 weeks of hearings we participated in during 1977. The least you could do would be to strike out the word may (3rd line from the bottom of the paragraph pertaining to metropolitan wastes).

For some reason, Chapter II on Lake Onalaska is not included in the new draft. Surely that current data should not be omitted. Perhaps it is included in some other appendix now.

Chapter VI, "Erosion & Land Treatment," has a negative overtone and leaves one with the feeling of hopelessness because of the cost analysis. Ed still maintains that past studies prove that benefits of proper land treatment exceed the costs. It would be well to add an explanation of the benefits other than curbing sedimentation that are derived from proper land-use practices, and not take it for granted that everyone knows what they are. Perhaps this is also the place to suggest that enforceable laws should be enacted to prohibit the destruction of shelter belts, planting row crops next to streams, cash-cropping on sloping terrains, further clearing of hillsides, over -grazing, and other malpractices.

Current land treatment practices are indeed inadequate to reduce sedimentation, but the tone of this report shakes my basic philosophy that the program must be accelerated. Every farm should have an acceptable land-use plan, and SCS should have sufficient personnel to make certain such plans are implemented. I suspect that the Conservation Needs Inventory is inaccurate, because it records lands for which conservation plans were once made, but with constant change of ownership, no one knows if they are being used and the personnel is inadequate to find out. We should be asking outright for the funds to get men back into the field and sell the program. Congress should be made aware of the reasons why the SCS program is slowed down. Soul scientists, engineers, agronomists, foresters and farm planners can't get the job done sitting behind a desk all wound up in red tape. This may be the reason why so many employees feel thwarted, or should I say defeated, because they can't get out and do what should be done.

Furthermore, somewhere in this report, we should suggest to Congress that farmers be given better cost-sharing incentives to encourage more proper land-use practices, and recommend perhaps, that subsidies should be denied land-owners who do not comply.

Ed and I do not understand why you put so much emphasis on the cost of maintenance. Granted, dams deteriorate and fill up with silt that must be removed, but as far as strip-cropping and terracing are concerned, the maintenance is negligibe.

Gary, I intend the above, sketchy comments to be constructive. The report was sent to me to be reviewed, and I have been frank and candid, as usual, in stating some of my feelings. You need not take the time to answer this letter, but do please send me a copy of the final draft.

Sincerely,

Dorothy

Dorothy D. Hill
President

DDH:jak
cc: Jerry Hytry
Dan McGuiness

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May 21, 1979

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Mr. Gary S. LePage, Chairman
Sediment and Erosion Work Group
GREAT I
U. S. Soil Conservation Service
316 North Robter Street, Room 200
St. Paul, MN 55101

Dear Mr. LePage:

We have noted with much interest the conclusions of your work group, and especially your recommendations regarding upland erosion control.

Soil and water conservation districts (SWCD) in the major sediment source areas in western Wisconsin would appreciate an opportunity to cooperate with the Corps of Engineers, and other appropriate agencies, in a special effort to achieve an 80% level of land adequately protected against soil erosion in identified special problem areas. This Board stands ready to assist the districts in such an effort in several ways.

I would infer from your conclusions and recommendations that the Corps would be well advised to provide funds for a special program to reduce soil erosion in major sediment source areas, as a cost-effective means of reducing channel dredging costs and some of the adverse environmental consequences of excessive upland erosion to the backwater lakes. We note that the individual soil and water conservation districts, and this Board as well, are authorized to receive and administer grants of funds from federal sources, including the Corps. Moreover, the SWCDs have signed memoranda of understanding with the Corps of Engineers which would provide the basis for such a cooperative effort.

Your second recommendation, regarding a research and demonstration program for no-till farming, is also of considerable interest to us and to some of our associates in the University of Wisconsin, College of Agriculture and Life Sciences. However, I would strongly urge that a broader concept known as "conservation tillage" be considered. This allows for much greater flexibility and freedom of choice in bringing the principles of erosion control through tillage techniques into harmony with an individual farmer's operational needs. Non-inverting tillage systems based on some form of the chisel plow appear much more promising for Wisconsin conditions than do no-till systems. However, in specific cases the best solution depends on a number of factors, and the array of questions associated with no-till, minimum tillage, or reduced tillage farming certainly deserve thoroughgoing research.

Obviously there is wide interest in tillage systems which will permit use of the runoff and erosion control benefits of rough, residue covered cropland surfaces. I am certain that my colleagues in the University of Wisconsin would be interested in participating in tillage research and demonstration projects.

The problem of sedimentation in the backwater lakes seems to say to me that "you can't fool Mother Nature". I assume these lakes, as they presently exist, are largely creatures of the dam building program. I wonder what upper limit must be placed on sedimentation rates in those lakes, and whether that low a rate could be achieved, practically. And I wonder whether we have created a hydraulic regime, with our flood controlling dams and navigational locks, that is simply not compatible with indefinite maintenance of those backwater lakes. Perhaps the situation is not nearly as grim as it seem to me, from my very limited knowledge base. The upper Mississippi River Valley scene that I see on my mental A.D. 2500 videoscreen is not very pretty.

Sincerely,

Leonard C. Johnson

Leonard C. Johnson
Research and Development Director

LCJ/sv
cc: Eugene Savage
Leo Walsh
Art Peterson

ATTACHMENT B

SEDIMENT TRANSPORT IN THE UPPER MISSISSIPPI RIVER WITHIN THE ST. PAUL DISTRICT

PREPARED BY

ENGINEERING RESEARCH CENTER
COLORADO STATE UNIVERSITY

NOVEMBER 1979

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INTRODUCTION

The Upper Mississippi River has been modified with locks, dams, dikes and bank revetment to provide a 9-foot navigation channel. These structures have an effect on low water and sediment movement through the study reach. Moreover, upstream dams have decreased the amount of sediment coming into the study reach. At low and intermediate flows, the dams raise pool levels above the natural level. This increases the depth of flow, decreases the flow velocities and sediment movement. Thus, flow velocities and sediment transport at low and intermediate flows are less in the pools than in the natural river.

At low and intermediate flows, the velocity in the upper end of a pool is generally greater than in the lower end. As the sediment transport rate is largely dependent on the flow velocity, the sediment transport rate at the upper end of the pool is greater than at the lower end and is also greater than the supply rate from the pool immediately upstream. The result is that bed erosion occurs in the upper reach of the pool and deposition occurs in the lower reach.

At high flows, the gates are opened above the water level and flow conditions approach the natural river state. During floods, the portion of the river that was eroded at low flow (the upper end of the pool) carries less sediment than that supplied from upstream. This results in deposition. In contrast, erosion occurs in the portion of the river that was aggraded at low flow (the lower end of the pool). This erosion and deposition occurs because of the locks and dams and is repeated on a yearly cycle.

The river crossing areas in a pool accumulates a slightly larger amount of sediment during the deposition part of the cycle than during the erosion part. Conversely, the deep areas in the river tend to deepen. Thus over a long period of time, the shallow areas undergo a net aggradation and the deep areas in the river channel deepen slightly.

The creation of 9-foot navigation channel also affects the sediment inflow from tributaries by changing the base flow conditions, which in turn, changes the erosion and deposition patterns in the Upper Mississippi main stem. In addition, dredging to maintain the 9-foot navigation channel also affects the river geomorphology. A comparison of 1929, 1938, and 1975 bed profiles in Pools 4-8 in the Upper Mississippi River clearly shows that the river bed in the main channel has generally degraded since the operation of the 9-foot channel (Simons and Chen, 1979). This indicates that the St. Paul District has dredged more bed material than that supplied from tributaries and upland watersheds. If this trend continues, dredging requirements to maintain the 9-foot channel will reduce with time. Therefore, it is possible to develop a better dredging policy by considering a system-wide impact of dredging, diking, control of sediment supplies from tributaries, and other alternatives. A coupled one-dimensional/two-dimensional water and sediment routing model has been developed for this purpose (Simons, et al., 1979a). It is the first time that a model has been developed in such a way that it can be utilized to effectively and accurately study a long reach of river system. This model should be updated, expanded and applied whenever conditions are appropriate.

Sediment supplies from tributaries and watersheds and the sediment transport ability of flow in the Upper Mississippi main stem are major factors controlling the maintenance of 9-foot navigation channel. These factors are discussed and their effects on the dredging requirements are assessed in the following sections.

SEDIMENT TRANSPORT

Basic Sediment Transport Modes

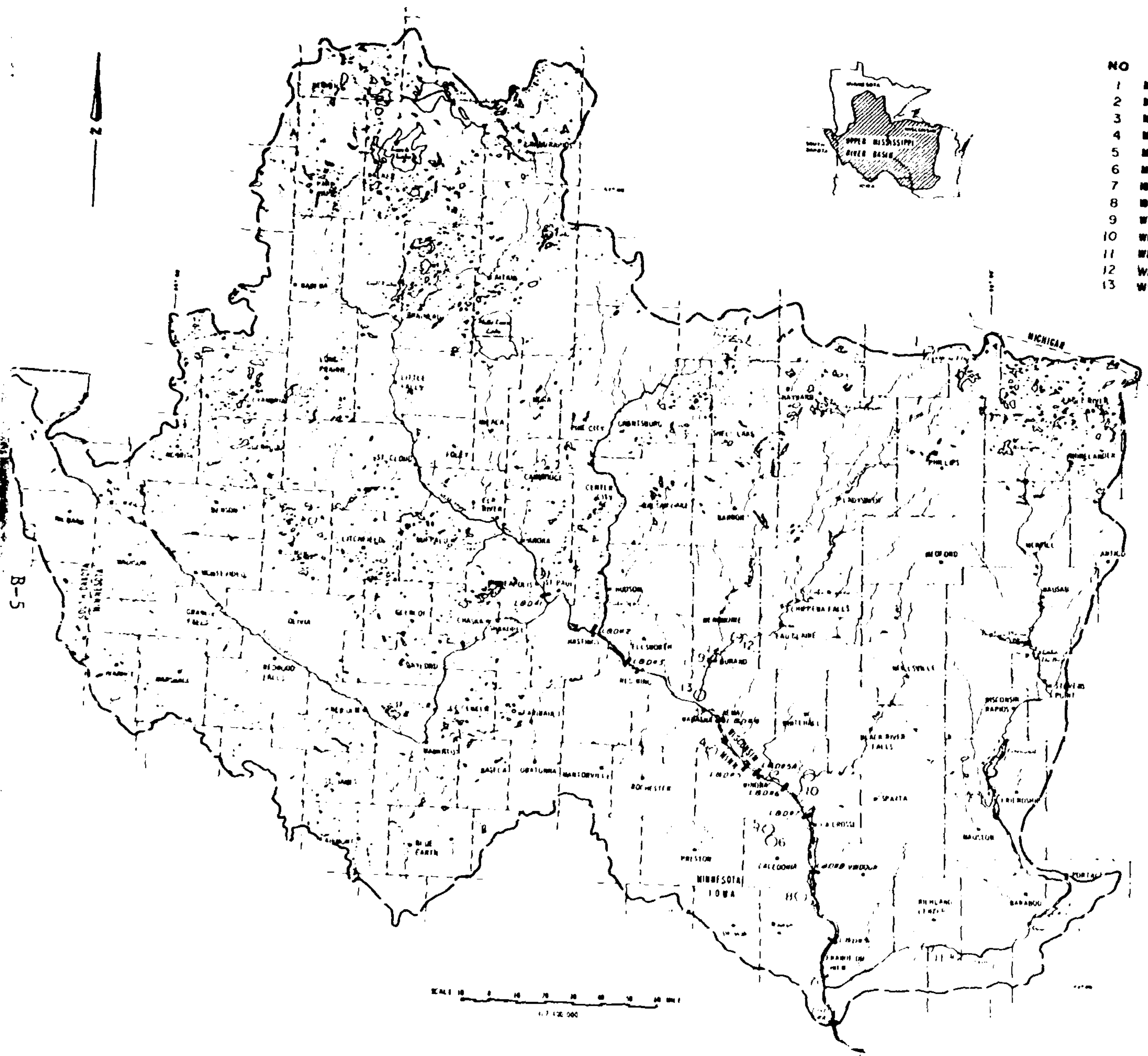
The flow in alluvial rivers usually transports sediment the size of which varies with avialability and the energy of the system. Every sediment particle which passes a particular cross section of the stream must satisfy two conditions: (1) it must have been eroded somewhere in the river basin above the cross section: (2) it must be transported by the flow from the place of erosion to the cross section. Each of these two conditions may limit the sediment rate at the cross section, depending on the relative magnitude of the two controls: the availability of the material in the river basin and the transport ability of the stream. In most streams the finer part of the load, i.e., the part consisting mainly of silt and clay that the flow can easily carry in large quantities, is limited by its availability in the watershed. This part of the load is designated as wash load. The coarser fraction of the load, i.e., the part mainly consisting of sand and gravel that is more difficult to move by flowing water moves at a limited rate that depends on the characteristics of the sediment and the transporting ability of the flow. This part of the load is designated as bed-material load The characteristics of the bed material are closely related to those of the bed material load. The total sediment load of a stream is the sum of the wash load and the bed-material load.

The source of wash load in the Upper Mississippi River Basin is mainly upland erosion. The wash load is carried by surface runoff into tributaries, and then into the Mississippi main stem. A portion of wash load may enter the backwater areas and deposit there, causing sedimentation problems.

Sediment particles are transported as bed load (this material moves by rolling, sliding and saltation along the bed) and/or as suspended load (suspended material is supported by flow for an appreciable length of time). The source of sand entering the river system is primarily bank erosion on tributary streams. If the supply of sand is larger than the transporting ability of flow, then a portion of sand load drops out. Excessive sand deposition must be removed by dredging to maintain the navigation channel. The sediment supply, the transport rate, the bed elevation changes, and the dredging quantities are closely related.

Validation of Sediment Data

The determination of sediment discharge is mainly based on field measurement supplemented by theoretical methods developed to compute the unmeasured load, or it is determined by sediment transport functions that relate the sediment discharge to the river hydraulics. The sediment sampling stations operated by the U.S. Geological Survey and the Soil Conservation Service in the Upper Mississippi River Basin are shown in Figure 1. The locations of these stations and type and year of data collected are described in Table 1. The data types include: suspended sediment concentration and size distributions, stream power parameters, bed-material size distributions, and bed load and size distributions. In order to meaningfully determine the sediment discharges,



LOCATION OF SAMPLING STATIONS

NO	STATE	RIVER	LOCATION
1	MINNESOTA	MISSISSIPPI RIVER	ANOKA - LOWRY AVE BRIDGE
2	MINNESOTA	MISSISSIPPI RIVER	WINONA BURLINGTON NORTHERN R.R. BRIDGE
3	MINNESOTA	ZUMBRO RR R	KELLOGG
4	MINNESOTA	WHITEWATER RIVER	NEAR BEAVER
5	MINNESOTA	ROOT RIVER	NEAR HOUSTON
6	MINNESOTA	SO FORK ROOT RIVER	NEAR HOUSTON
7	IOWA	MISSISSIPPI RIVER	McGREGOR
8	IOWA	UPPER IOWA RIVER	DORCHESTER
9	WISCONSIN	CHIPPEWA RIVER	DURAND
10	WISCONSIN	BLACK RIVER	NEAR GALESVILLE
11	WISCONSIN	WISCONSIN RIVER	MUSCOTA
12	WISCONSIN	CHIPPEWA RIVER	NEAR CARYVILLE
13	WISCONSIN	CHIPPEWA RIVER	NEAR PEPIN

○ SAMPLING STATION

SEDIMENT SAMPLING
STATIONS MAP
GREAT I
UPPER MISSISSIPPI RIVER BASIN
IOWA, MINNESOTA, SOUTH DAKOTA AND WISCONSIN

Figure 1. Sediment Sampling Stations Map, Upper Mississippi River Basin

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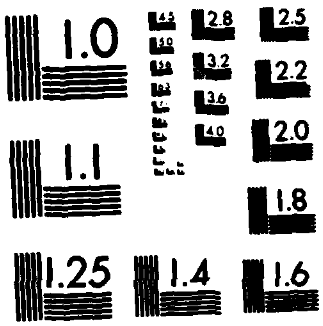

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 1. Measuring Stations with Sediment Transport Data

STATION	RIVER	STATION NUMBER	RIVER MILE	LATITUDE	LONGITUDE	TYPE* and YEAR OF DATA			
						A	B	C	D
1) Nr Anoka	Mississippi	05288500	864.80	45°07'36"	93°17'48"	76	-	75-76	-
2) At Winona	Mississippi	05378500	725.70	44°03'20"	91°38'15"	75-77	-	76-77	-
3) At Kellogg	Zumbro	05374900	-	44°18'43"	92°00'14"	76	-	76-77	-
4) Nr Beaver	Whitewater	05376800	-	44°09'03"	92°00'19"	75-77	-	75-77	-
5) Nr Houston	Root	05385000	-	43°46'05"	91°35'11"	76-77	-	76-77	-
6) Nr Houston	South Fork	05385500	-	43°44'19"	91°33'50"	76-77	-	76	-
7) At McGregor	Mississippi	05389500	633.40	43°01'29"	91°10'21"	75-78	-	75-78	-
8) Nr Dorchester	Upper Iowa	05388250	18.10	43°25'16"	91°30'31"	75-78	-	75-78	-
9) At Durand	Chippewa	05369500	17.40	44°37'40"	91°58'10"	75-78	75-78	75-78	75-78
10) At Galesville	Black	05382000	-	44°04'22"	91°17'41"	77-78	77-78	77-78	76-78
11) At Muscoda	Wisconsin	05407000	-	43°11'54"	90°26'26"	77-78	77-78	77-78	76-78
12) Nr Caryville	Chippewa	-	-	-	-	76-78	76-78	76-78	76-78
13) Nr Pepin	Chippewa	-	-	-	-	76-78	76-78	76-78	76-78

* Type A Data: Suspended sediment concentration and size distributions
Type B Data: Stream power parameters
Type C Data: Bed-material size distributions
Type D Data: Bed load and size distributions

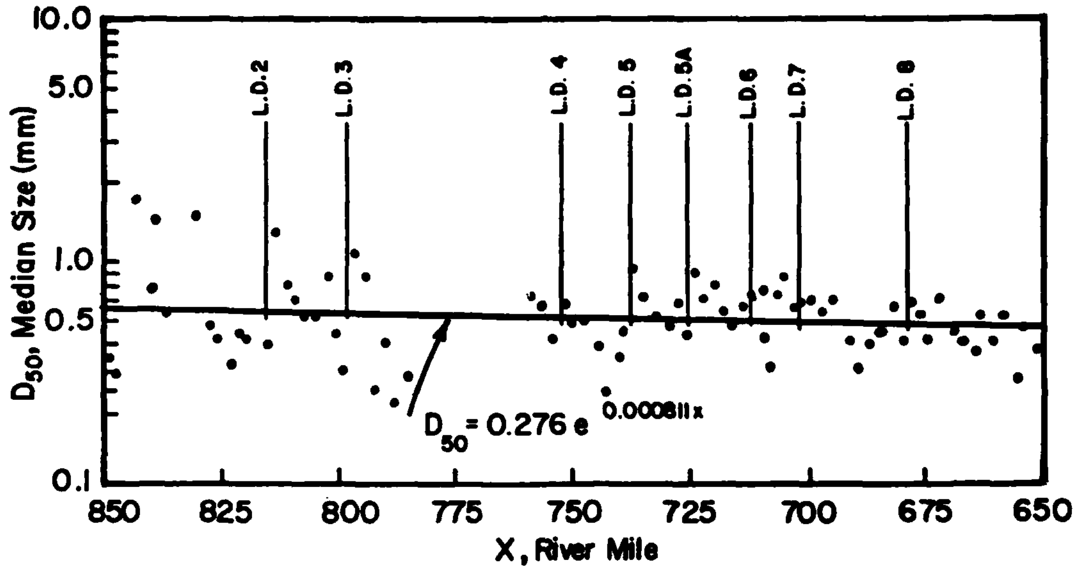

Figure 2. Median Size of Bed Maerial in the Upper Mississippi River

these data have to be reasonably accurate. Relevant variables are examined to validate the consistency of the data.

The bed material samples collected in the Upper Mississippi River main stem were analyzed by using sieve analysis (for sand fraction) and hydrometer analysis (for silt and clay fraction) to determine the size distribution. The median size of bed material at different river sections is plotted on Figure 2. It was found the median bed material size varied widely with a decreasing trend in downstream (from 0.55 mm to 0.45 mm). In the river reach between Miles 785 and 765 lies Lake Pepin, which traps most of the sand entering the lake from upstream. The bed material in the upper reach of Lake Pepin is fine sand and in the middle and lower reaches, is mainly silt and clay. Major sediment contributors such as the Chippewa River have significant effects on the bed material characteristics in the Upper Mississippi River main stem. Erosion generally occurs immediately downstream of each lock and dam. The size of bed material is coarser than average within these areas as shown in Figure 2. Since the size distribution of collected bed material samples appears to be reasonable and also the bed material samples are usually reliable, the quality of bed-material data is considered good.

Instantaneous suspended load and bed load at a river section fluctuates greatly due to the flow turbulence. Therefore, collection of these data are usually done on a time-averaged basis. All the suspended sediment data collected by the U.S. Geological Survey follow standard procedures which have been extensively tested and verified. The quality of these suspended sediment data is usually good. Figures 3 through 7 show plots of suspended sediment discharge versus water

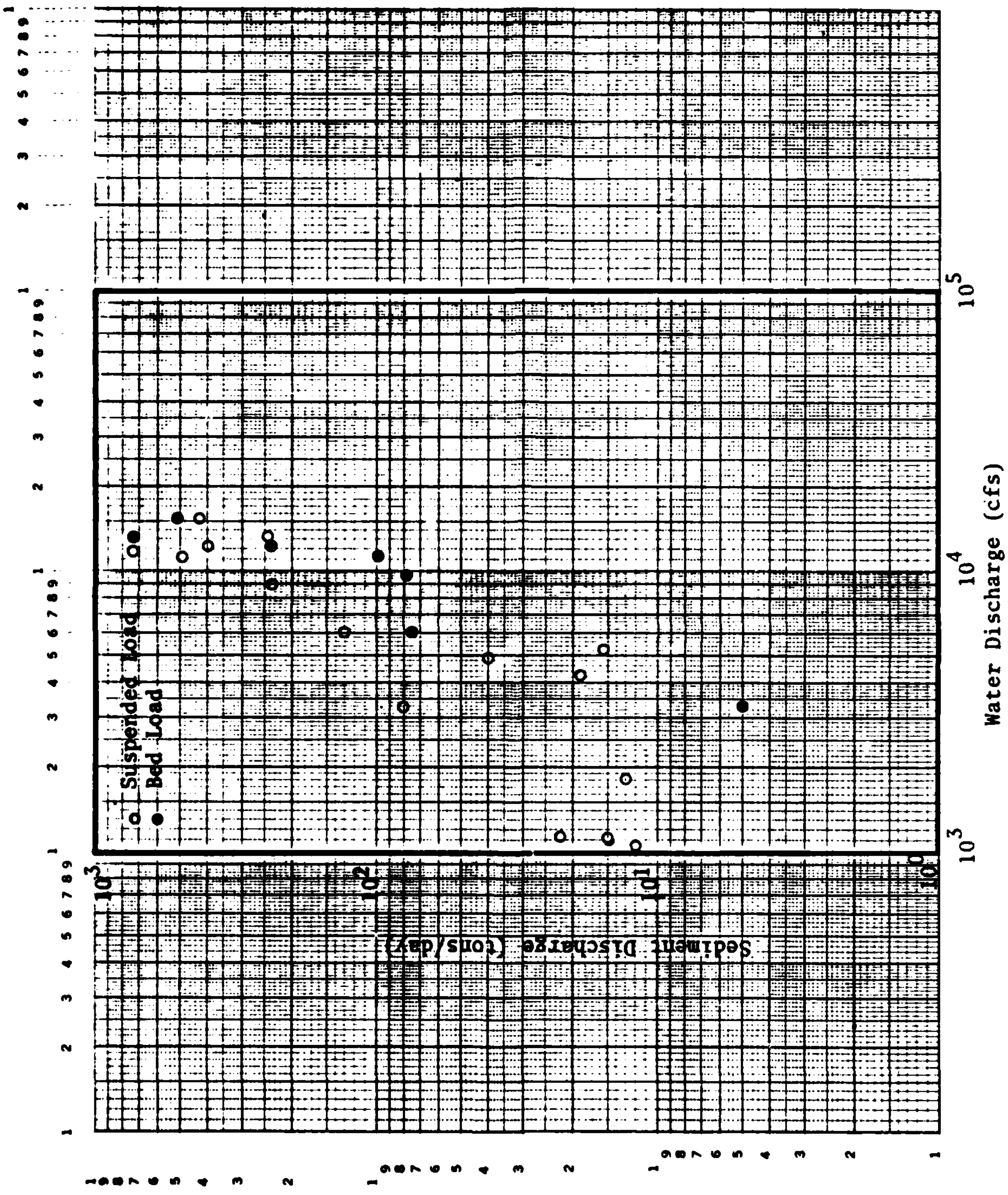

Figure 3. A Plot of the Sediment Discharges versus the Water Discharges in the Chippewa River near Caryville

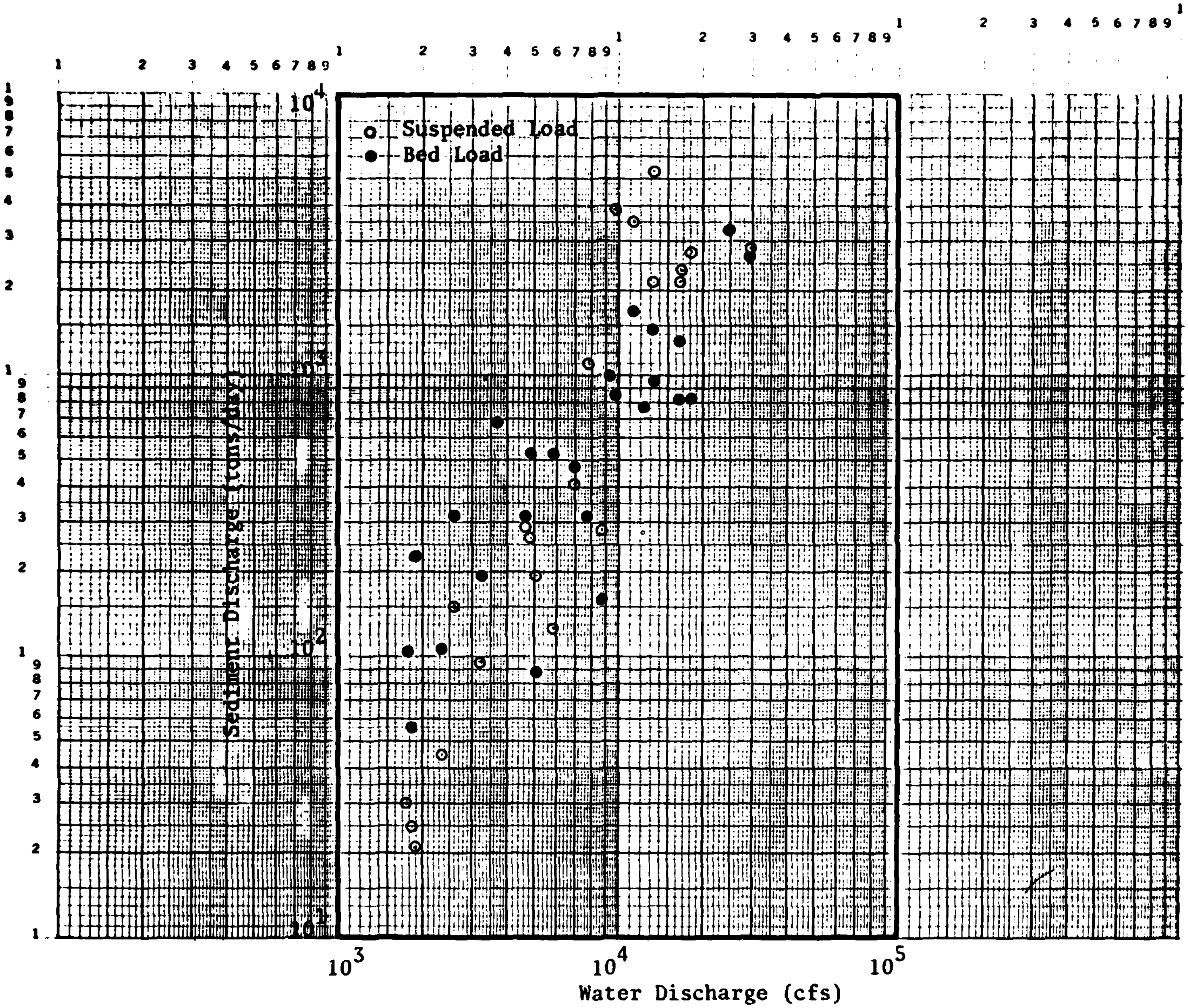

Figure 4. A Plot of the Sediment Discharge versus the Water Discharges in the Chippewa River at Durand

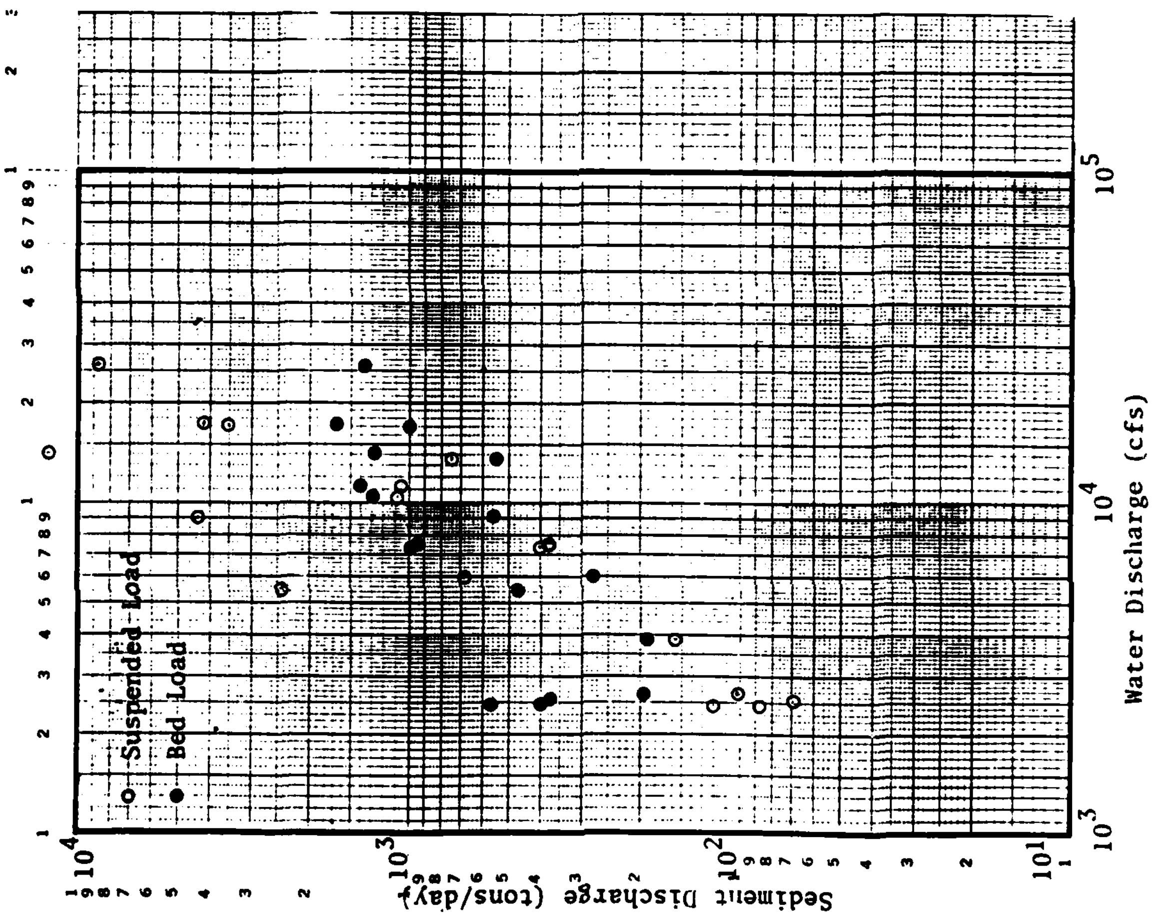

Figure 5. A Plot of the Sediment Discharges versus the Water Discharges in the Chippewa River near Pepin

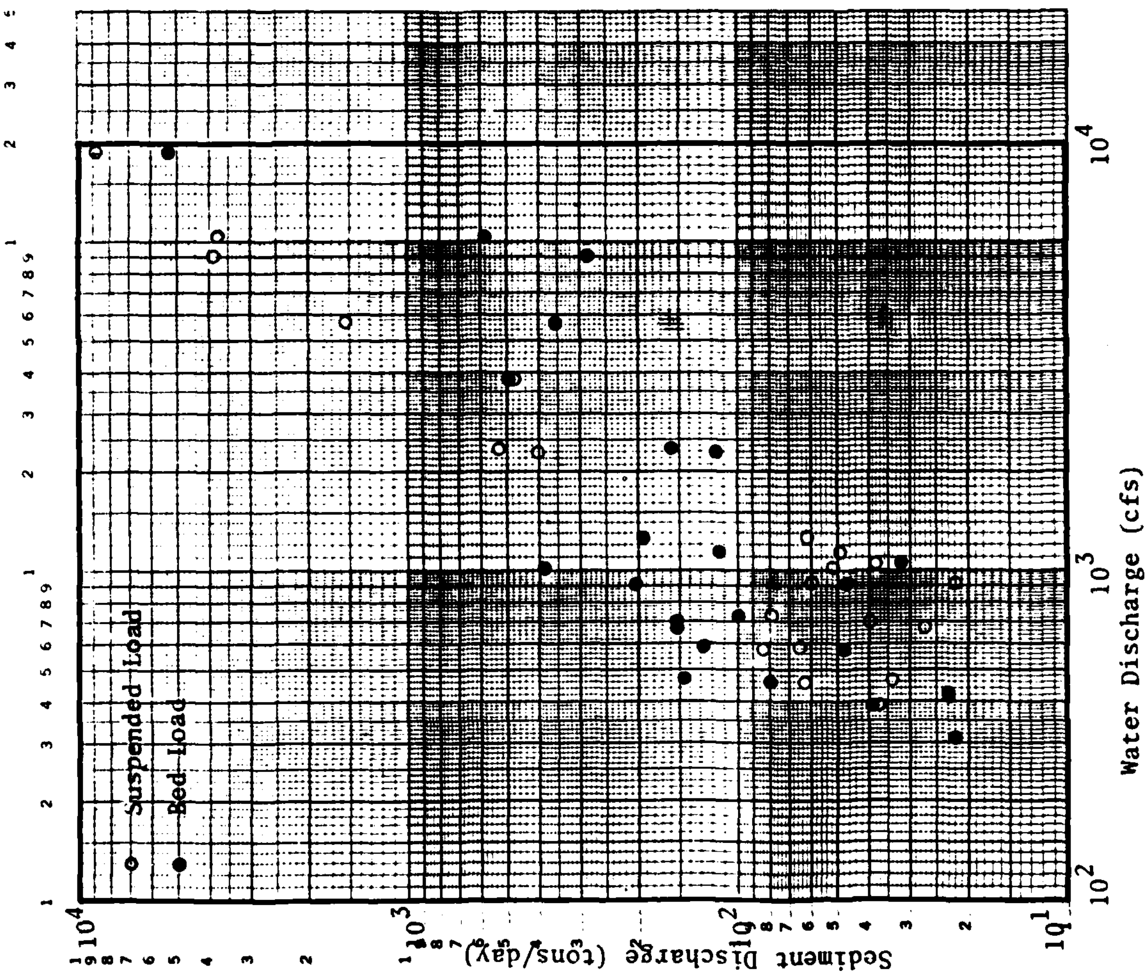

Figure 6. A Plot of the Sediment Discharges versus the Water Discharges in the Black River near Galesville

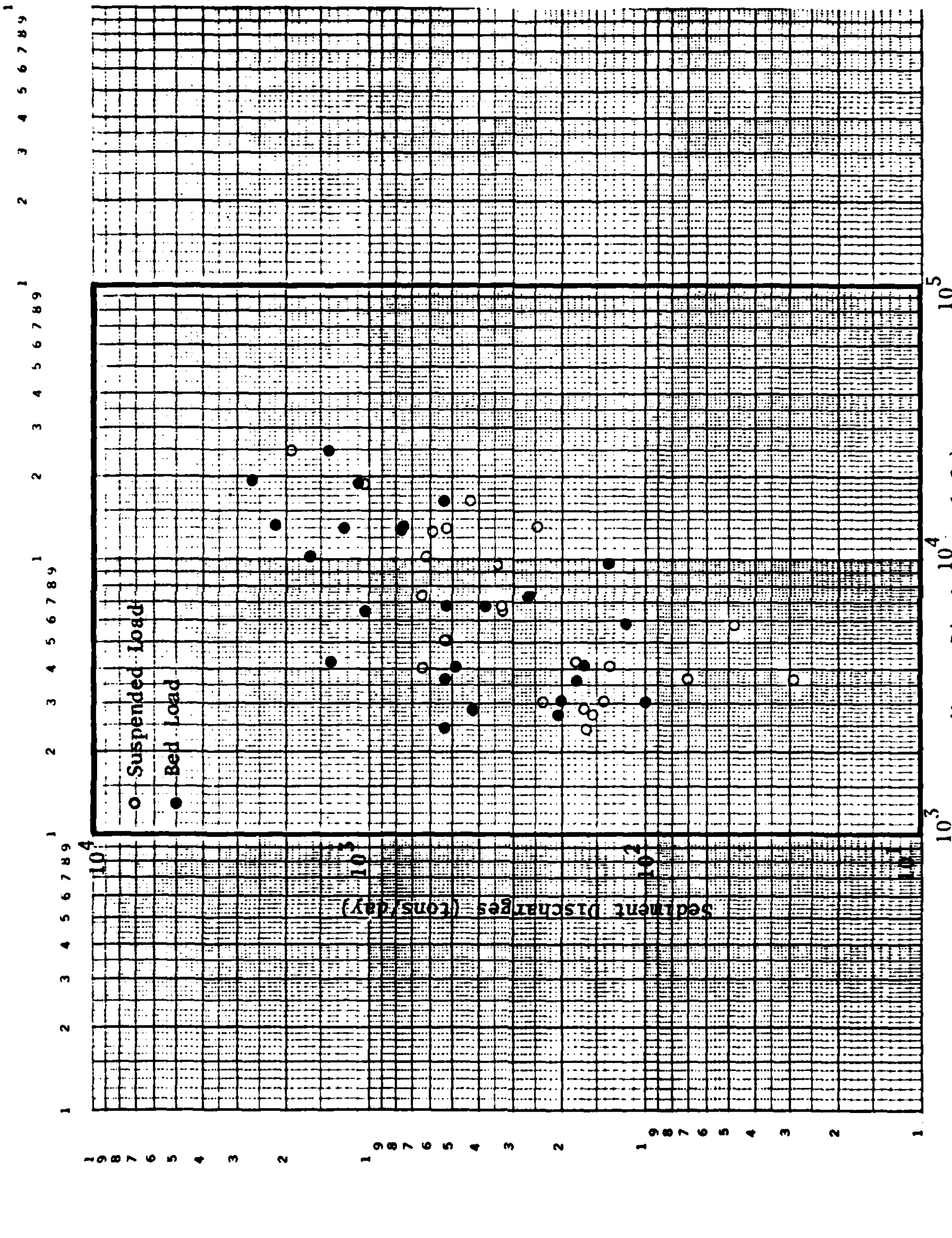

Figure 7. A Plot of the Sediment Discharges versus the Water Discharges in the Wisconsin River at Muscoda

discharges. The data points scatter but follow consistent trends. Bed loads collected by a Helley-Smith Bed-Load Sampler are also plotted on Figures 3 through 7. Good trends between bed loads and water discharges indicate that these bed load data are useful. However, because of the complexity in bed formation, sampling errors of bed load measurements are usually larger than that of suspended load measurements. There is no universally accepted bed-load sampler available today. Additional tests of the Helley-Smith Bed-Load Samplers are necessary to validate their accuracy.

The stream power parameters measured include velocity, depth, water temperature, and water surface slope. In general, velocity, depth and temperature data are quite accurate. However, the water surface slope is usually difficult to measure, especially in the Mississippi River where the slope is quite mild, on an order of 0.5 ft/mile. It is a general practice to substitute the slope by using velocity and depth for determining the sediment discharges.

Determination of Sediment Discharges

The measured suspended sediment concentration and hydraulic conditions were utilized to determine the unmeasured sediment load by using Colby's method (1957). The most accepted method for determining the total sediment load is the Modified Einstein's Procedure (Colby and Hembree, 1955). However, this method requires the measured suspended sediment size distributions, which are not available for most collected sediment data.

The computed total sediment load was divided into the bed-material load (sand) and the wash load (silt and clay). The bed-material loads per unit width were plotted as a function of velocities in Figures 8 through 10, and the wash loads were plotted as a function of water

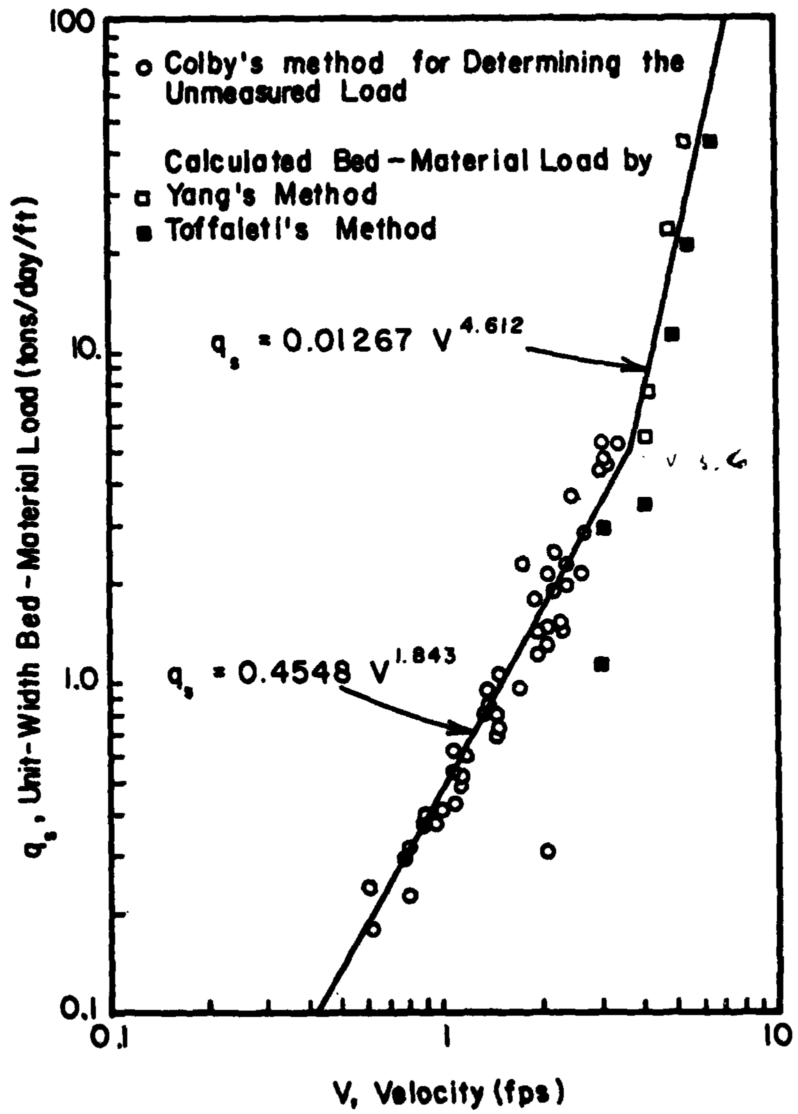

Figure 8. Relation between Bed-Material Load and Velocity in the Upper Mississippi River at Winona

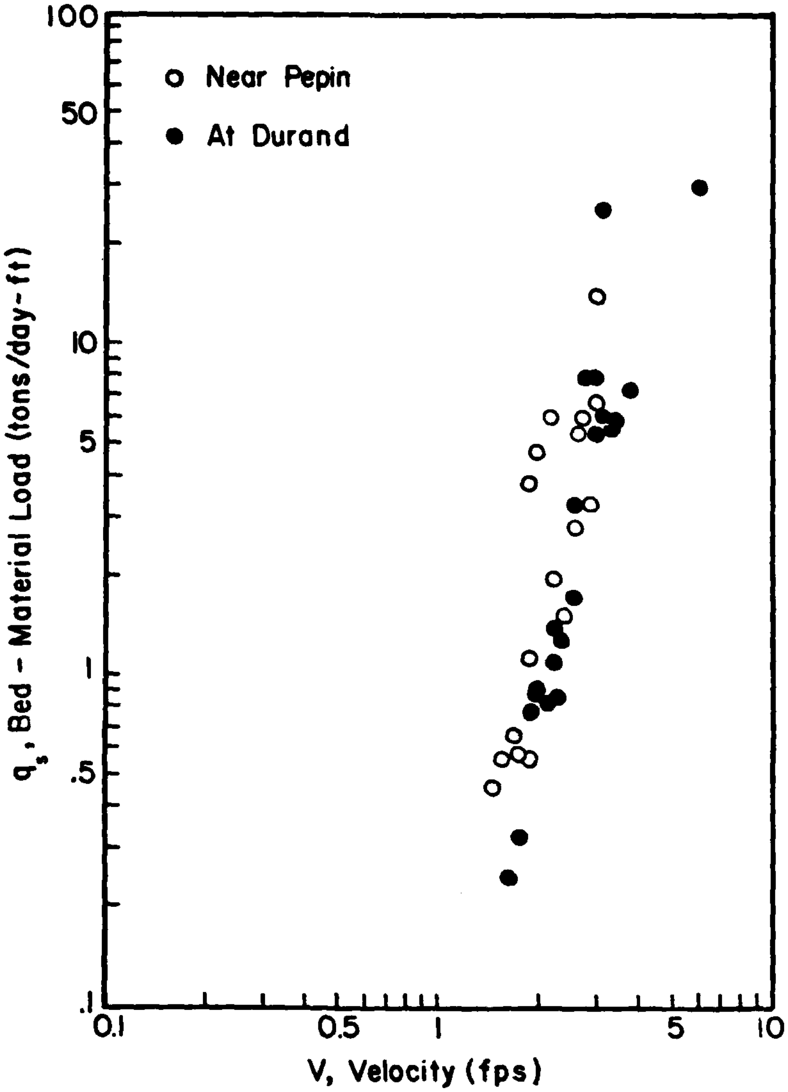

Figure 9. Relation between Bed-Material Load and Velocity in the Lower Chippewa River

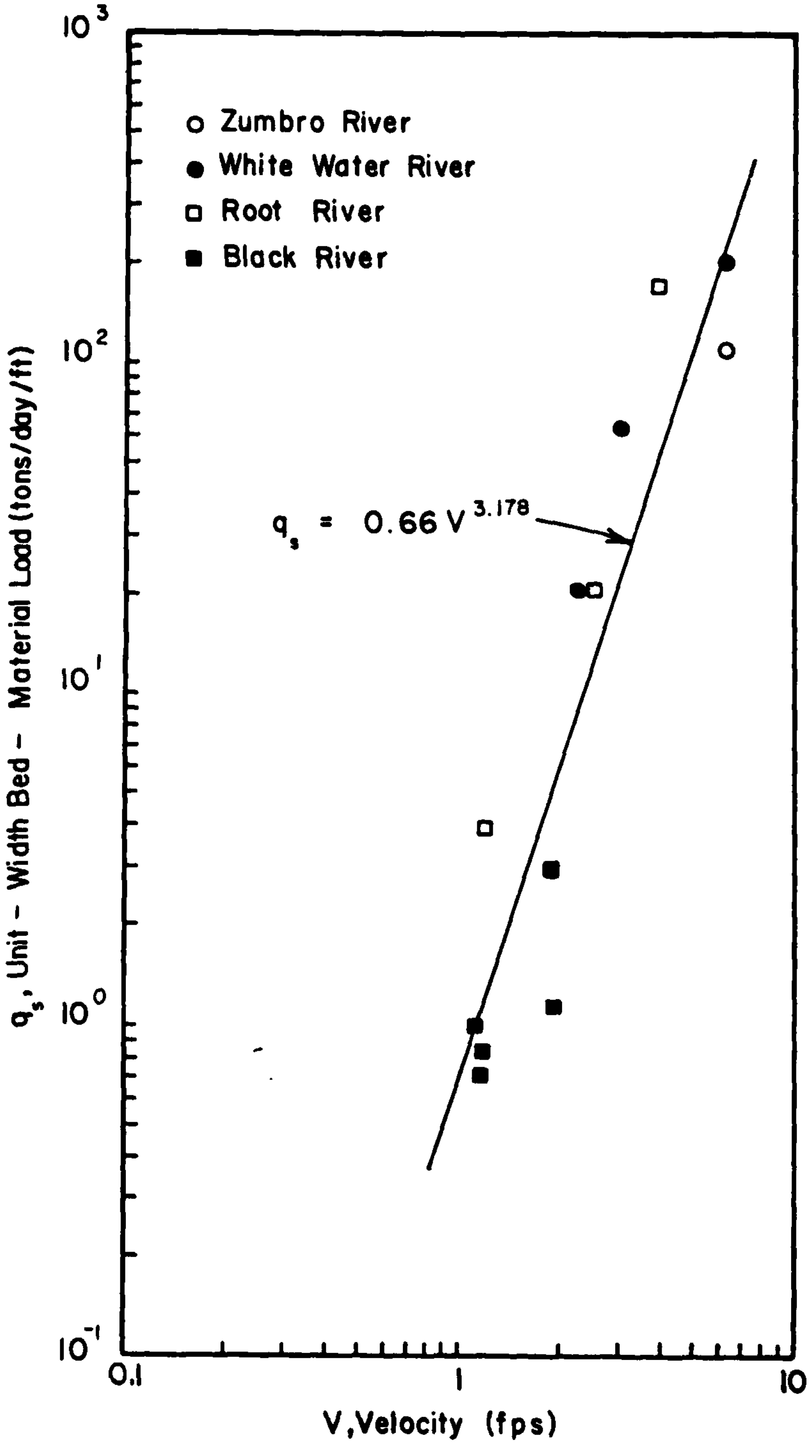

Figure 10. Relation between Bed-Material Load and Velocity in the Lower Zumbro, Whitewater, Root and Black Rivers

discharges in Figures 11 through 14. These relations were then input to the one-dimensional mathematical model of Pools 5- (Simons, et al., 1979b) to compute annual sediment loads for an average year. The computed bed-material and wash load discharges through each lock and dam and from major tributaries in the study reach are given in Tables 2 and 3 respectively. Most of the bed-material load and wash load moves in the main channel. Only the wash load can be carried by lateral flow reaching the back water areas. Deposition of this wash load is slowly filling the backwater areas with an average rate of about 2-3 cm/year. If the present rate of sedimentation is allowed to continue, most of the backwater areas will become marshland within the next century. The main source of fine sediment is upland erosion. Local rehabilitative works may extend the existence of the Upper Mississippi backwater areas. However, prevention of sediment production at the source is the only solution for maintaining the existence of these backwater lakes.

COMPARISON BETWEEN DREDGING REQUIREMENTS AND BED-MATERIAL DISCHARGES

The importance of dredging for the maintenance and improvement of a navigable waterway in the Upper Mississippi River was clearly recognized in the authorizing legislation for the 9-foot channel project. The River and Harbor Act of 1930 provided for a navigation channel 9 feet deep and of adequate width from the mouth of the Missouri River to St. Paul, to be established by construction of a series of locks and dams, and to be maintained by channel dredging.

The accumulation of coarse sediment (sand) necessitates periodic dredging to maintain the 9-foot navigation channel. For the Pool 4, 5, 5A, 6, 7 and 8 reaches on the Upper Mississippi River, dredging data have been compiled by the St. Paul District (1974) since 1934.

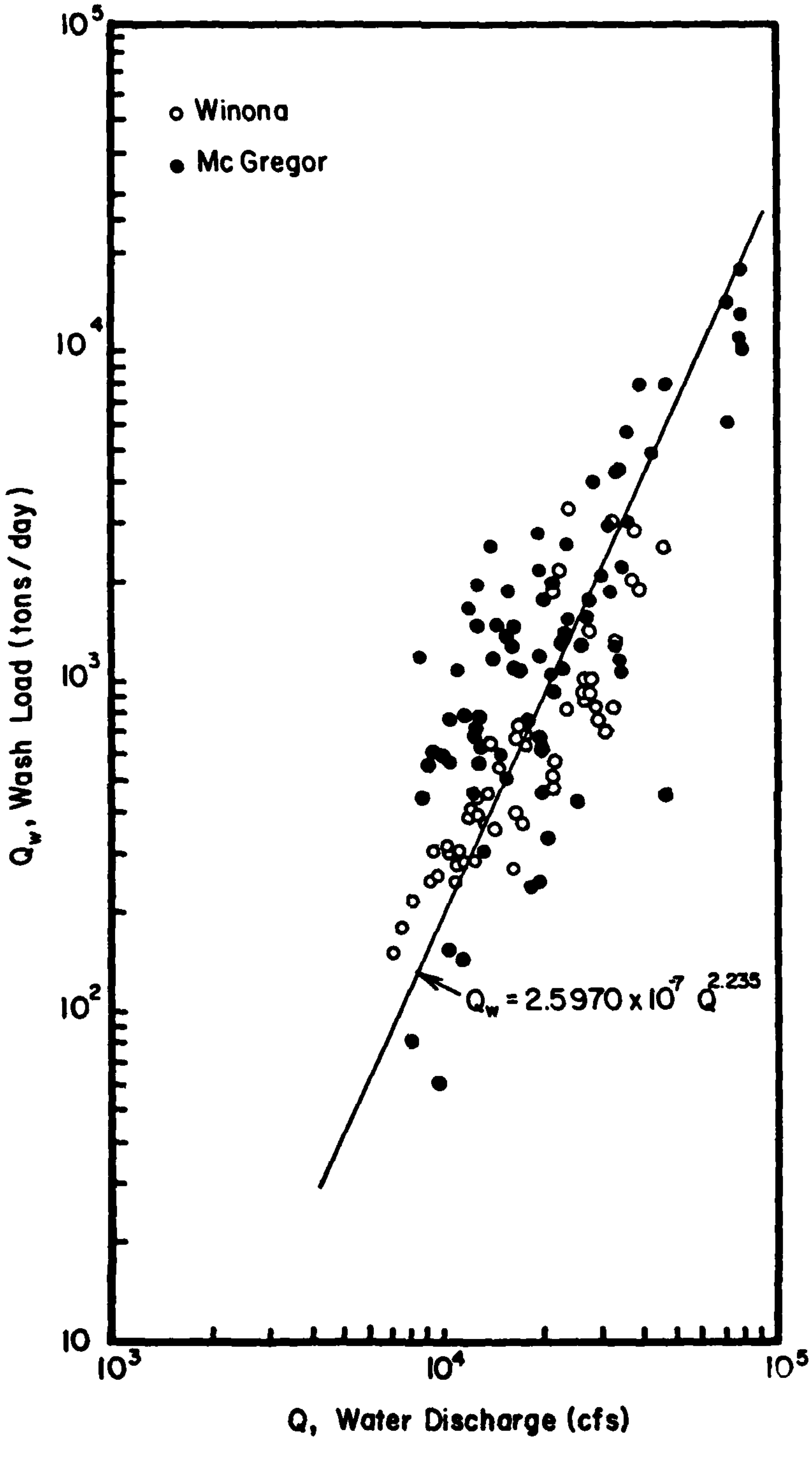

Figure 11. Relation between Wash Load and Water Discharge in the Upper Mississippi River at Winona and McGregor

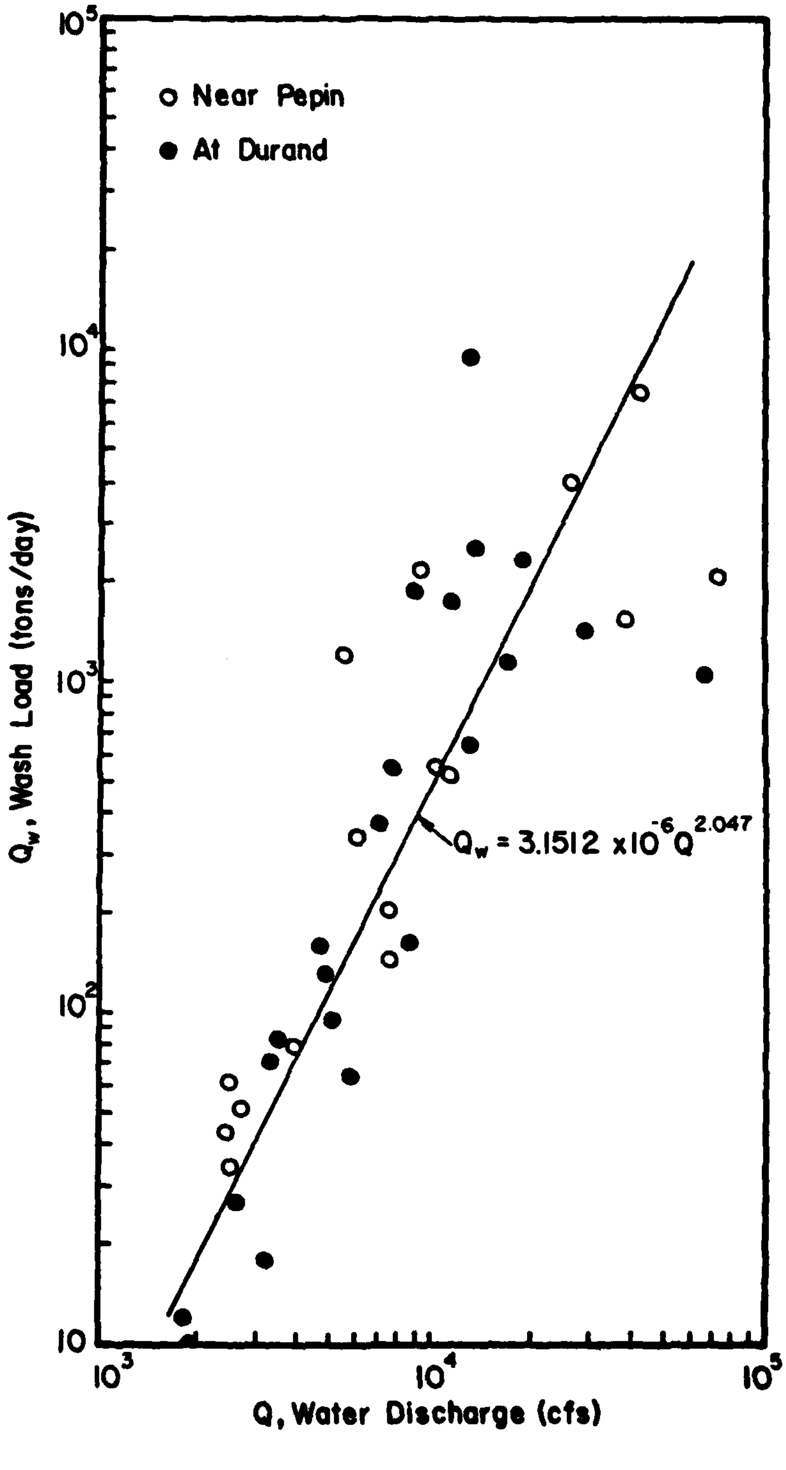

Figure 12. Relation between Wash Load and Water Discharge in the Lower Chippewa River

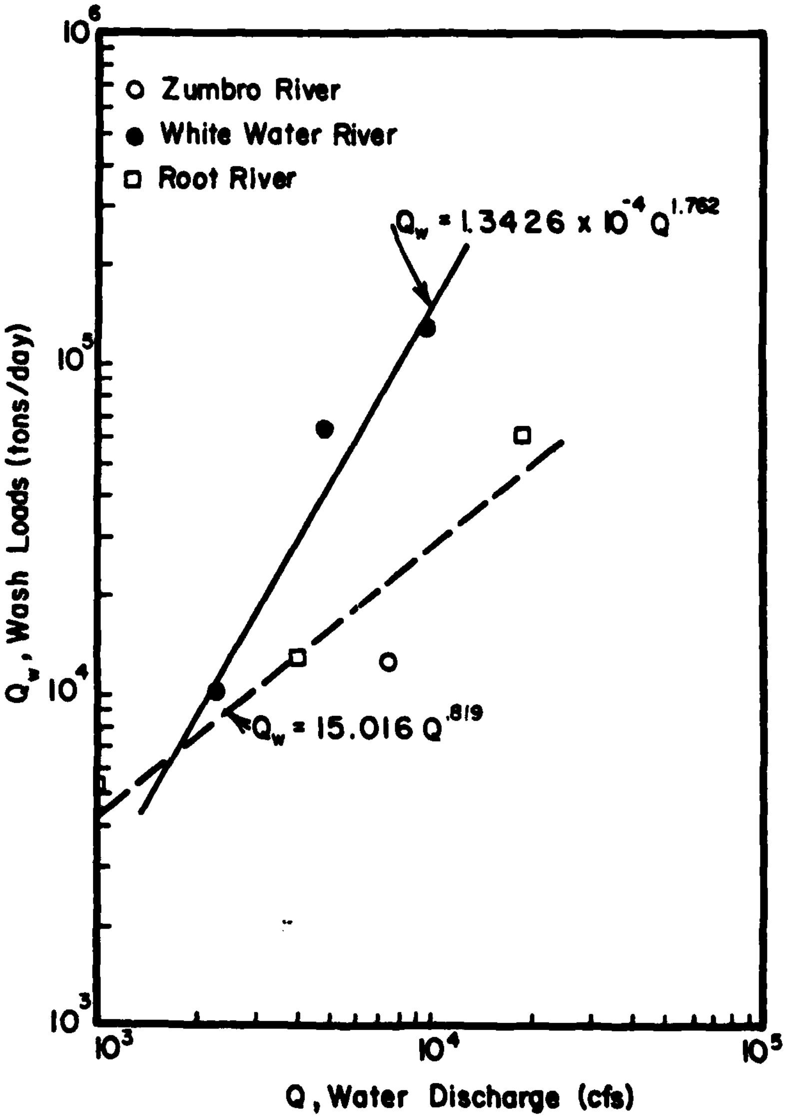

Figure 13. Relations between Wash Loads and Water Discharges in the Zumbro, Whitewater and Root Rivers

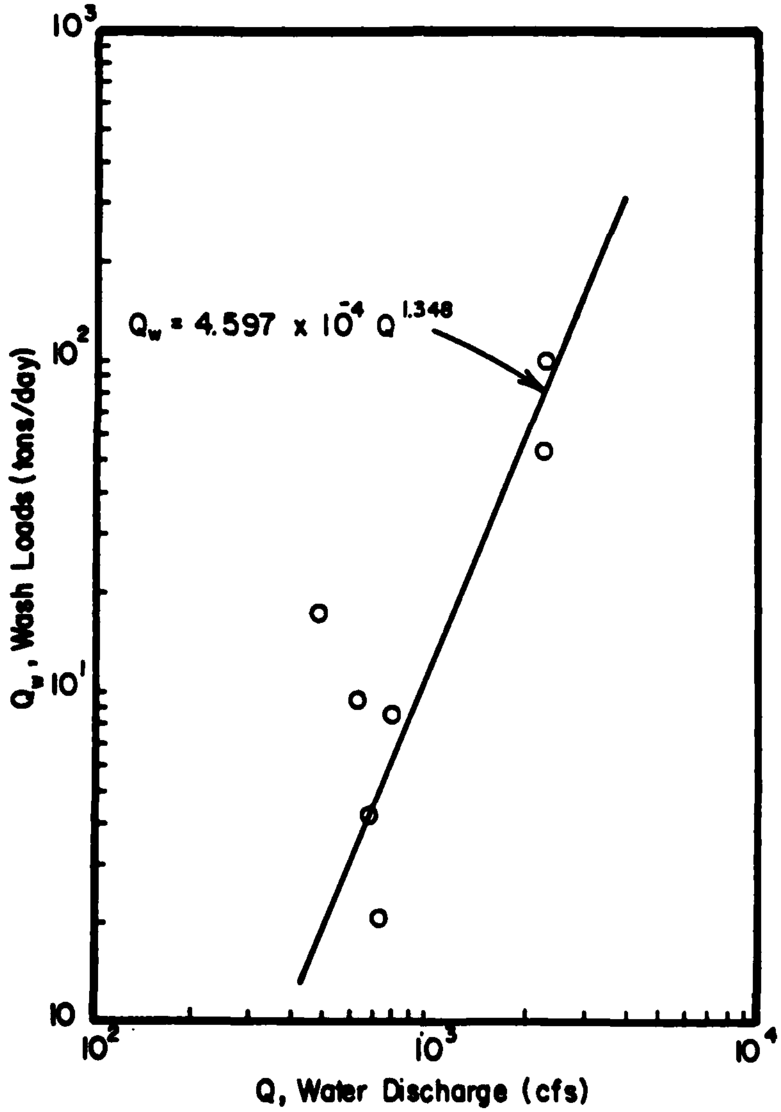

Figure 14. Relation between Wash Load and Water Discharge in the Black River

TABLE 2 Annual Bed-material Inflow and Outflow (tons/year) in Pool 4-8

Pools	Two-year annual hydrograph	Ten-year annual hydrograph
Pool 4		
• Inflow from Chippewa River	613,000	1,710,000
• Outflow to Pool 5	353,000	720,000
Pool 5		
• Inflow from Pool 4	353,000	720,000
• Inflow from Zumbro River	133,000	-
• Outflow to Pool 5A	230,000	569,000
Pool 5A		
• Inflow from Pool 5	230,000	569,000
• Outflow to Pool 6	242,000	352,000
Pool 6		
• Inflow from Pool 5A	242,000	352,000
• Outflow to Pool 7	305,000	570,000
Pool 7		
• Inflow from Pool 6	305,000	570,000
• Outflow to Pool 8	314,000	505,000
Pool 8		
• Inflow from Pool 7	314,000	505,000
• Inflow from LaCrosse River	-	106,000
• Inflow from Root River	57,000	109,000
• Outflow to Pool 9	214,000	333,000

TABLE 3. Annual Wash-load Discharge (tons/year) in Pools 4-8

Pools		Two-year annual hydrograph	Ten-year annual hydrograph
Mississippi River upstream of Chippewa River		445,000	1,482,000
Chippewa River		121,000	196,000
Lock and Dam 4		811,000	2,448,000
Zumbro River (only 1976 discharge data)		877,000	-
Whitewater River		-	-
Lock and Dam 5		906,000	2,487,000
Lock and Dam 5A		910,000	2,493,000
Trempealeau River		684,000	933,000
Lock and Dam 6	Zumbro & Root River Relation No Discharge factors of the Black	957,000	2,588,000
Black River		-	-
Lock and Dam 7		1,155,000	2,916,000
LaCrosse River		519,000	548,000
Root River		776,000	1,350,000
Lock and Dam 8		1,241,000	3,115,000

Annual dredging quantities range from a minimum of no dredging in some years to a maximum of 2,386 cubic yards in Pool 4 in 1938, 718,000 cubic yards in Pool 5 in 1938, 834,000 cubic yards in Pool 5A in 1935, 501,000 cubic yards in Pool 6 in 1935, 437,000 cubic yards in Pool 7 in 1934, and 930,000 cubic yards in Pool 8 in 1936. Average annual dredged volumes after lock and dam construction are shown in Table 4. Pool 4 below Lake Pepin has required the largest quantities of dredging (in terms of both entire reach and per mile) to maintain the navigation channels. The main factor is the large amount of sand supplied from the Chippewa River.

To establish a more direct relation between dredging requirements and geomorphic factors, the dredging quantities between Year 1956 and 1972 were plotted by location to the nearest river mile in Figure 15. Also, indicated in Figure 15 are the locations of the six locks and dams and tributary locations. In addition, the general morphologic character of the river at a given location in terms of pools, crossings, straight reaches and divided reaches is included.

It is found that dredging in this reach of the Upper Mississippi does not appear to be strongly related to tributary locations, except downstream of the Chippewa River. On the other hand, Figure 15 reveals a strong correlation between lock and dam locations, divided reaches and dredging requirements. Immediately below each lock and dam, a major scour hole usually developed. This scour hole increases the river depth so that dredging usually is not required at this location. However, the scour hole acts as a sediment source area and contributes to downstream sedimentation and dredging problems. Dredging trouble spots tend to be located above an near the pool control point in each

TABLE 4. Average Annual Dredging by Pool

Pool	Average Dredging Quantities		
	1936-1955*	1956-1972	1936-1972*
4	339,000 †	218,000	268,000
(below Lake Pepin)	(30,300) ††	(19,500)	(23,900)
5	258,400	168,400	219,500
	(17,600)	(11,500)	(14,900)
5A	193,100	97,900	148,100
	(20,100)	(10,200)	(15,400)
6	131,300	46,900	120,200
	(9,300)	(3,300)	(8,500)
7	161,900	94,500	130,100
	(13,600)	(7,900)	(10,900)
8	239,100	154,300	199,000
	(10,300)	(6,600)	(8,540)

* For Pools 5A, 6, 7 and 8, the average values are computed starting from Year 1937.

† Average dredging quantities in entire pool (cubic yards/year)

†† Average dredging quantities per mile of pool (cubic yards/mile-year)

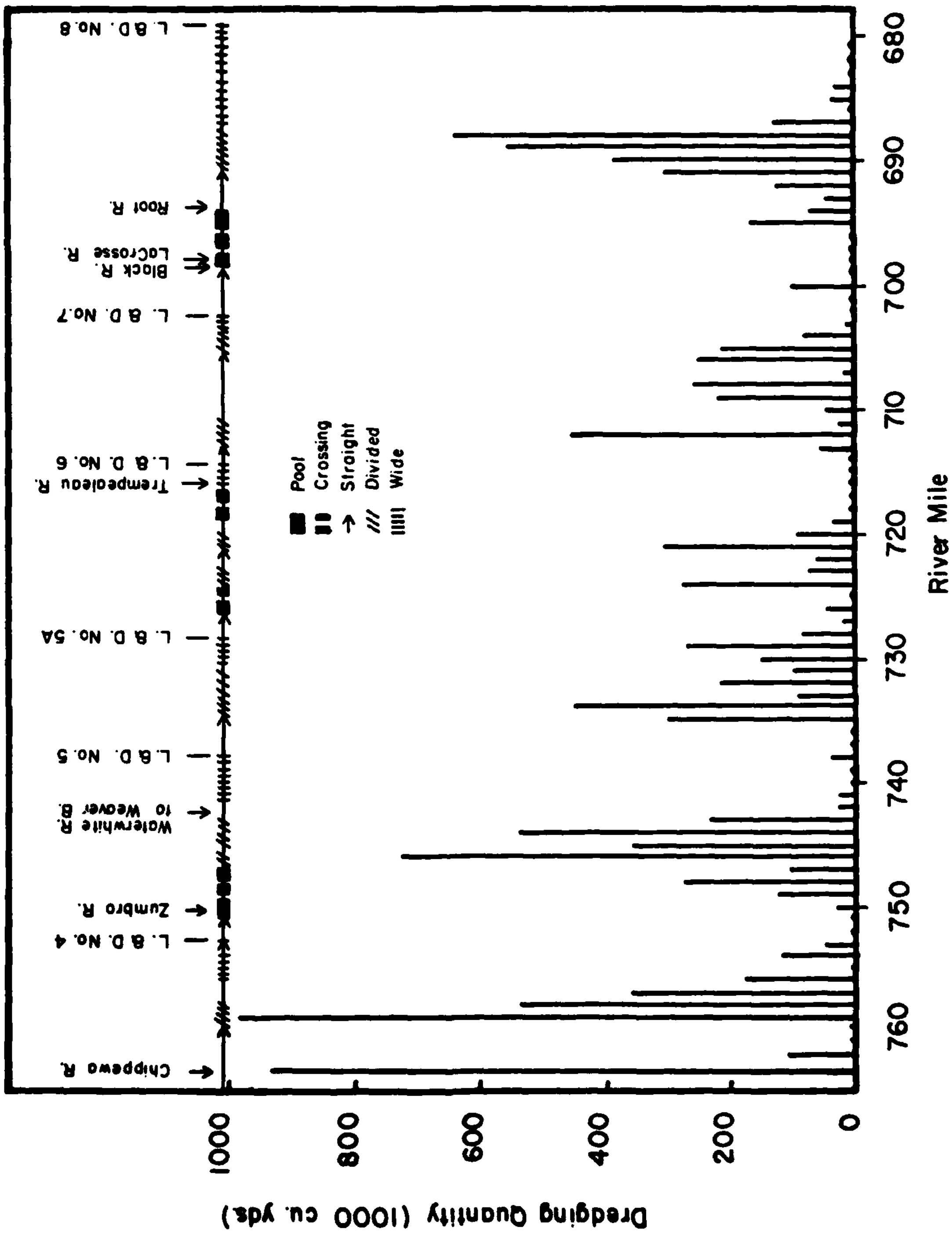

Figure 15 Dredging Quantities by Location in Pools 4 through 8, Upper Mississippi River (Years 1956-1972)

pool, where the river is flowing under more or less open river conditions. Between River Miles 760 and 685, the most serious dredging problems occur in straight reaches which are located above the pools primary control point and which are divided by alluvial islands.

COMPARISON BETWEEN THE DREDGING REQUIREMENTS AND BED-MATERIAL DISCHARGES

Tables 2 and 3 show that the Chippewa River is the major bed-material load contributor to the Upper Mississippi main stem. Only 10 - 20 percent of total load in the Chippewa is wash load. On the other hand, the Zumbro River, the LaCrosse River and the Root River carry more wash load than bed-material load. Comparing bed-material load inflows and outflows in Pools 4-8 in Table 2 indicates that in an average year bed levels in Pools 4, 5 and 8 aggrade if no dredgings are made in these pools. In a wet year with 10 years recurrence interval, bed elevations in Pools 5A and 7 also aggrade. This explains why ranks of dredging requirements are Pool 4, Pool 5, Pool 8, Pool 5A, Pool 7, and finally, Pool 6.

Comparison between bed-material discharges (Table 2) and dredging quantities (Table 4) indicates that except in Pool 4, the St. Paul District actually dredged more bed material than that supplied from tributaries and from the upstream pool. This has caused a general degradation in Pools 4 through 8.

It should be pointed out that in addition to bed-material supplied from tributaries and the upstream pool that contributes to dredging, other sediment sources include: (1) sediment derived from the erosion of riverbed immediately downstream of each lock and dam, and (2) return of the dredged material disposed of along banklines, on marshes and on islands.

The riverbed immediately downstream of each lock and dam is approaching a new equilibrium after more than 40 years of operation of the locks and dam systems. The bed material became coarser than the average size within the scoured areas as shown in Figure 2. This development decreases the sediment derived from these eroded areas. In addition, the Corps of Engineers has modified the disposal practice to better confine the dredged material to disposal sites. Considering these activities, it is believed that the dredging requirements to maintain the 9-foot navigation channel will reduce with time. The one-dimensional and two-dimensional water and sediment routing models developed at Colorado State University can be utilized to predict the future dredging requirements and to develop better dredging policies.

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